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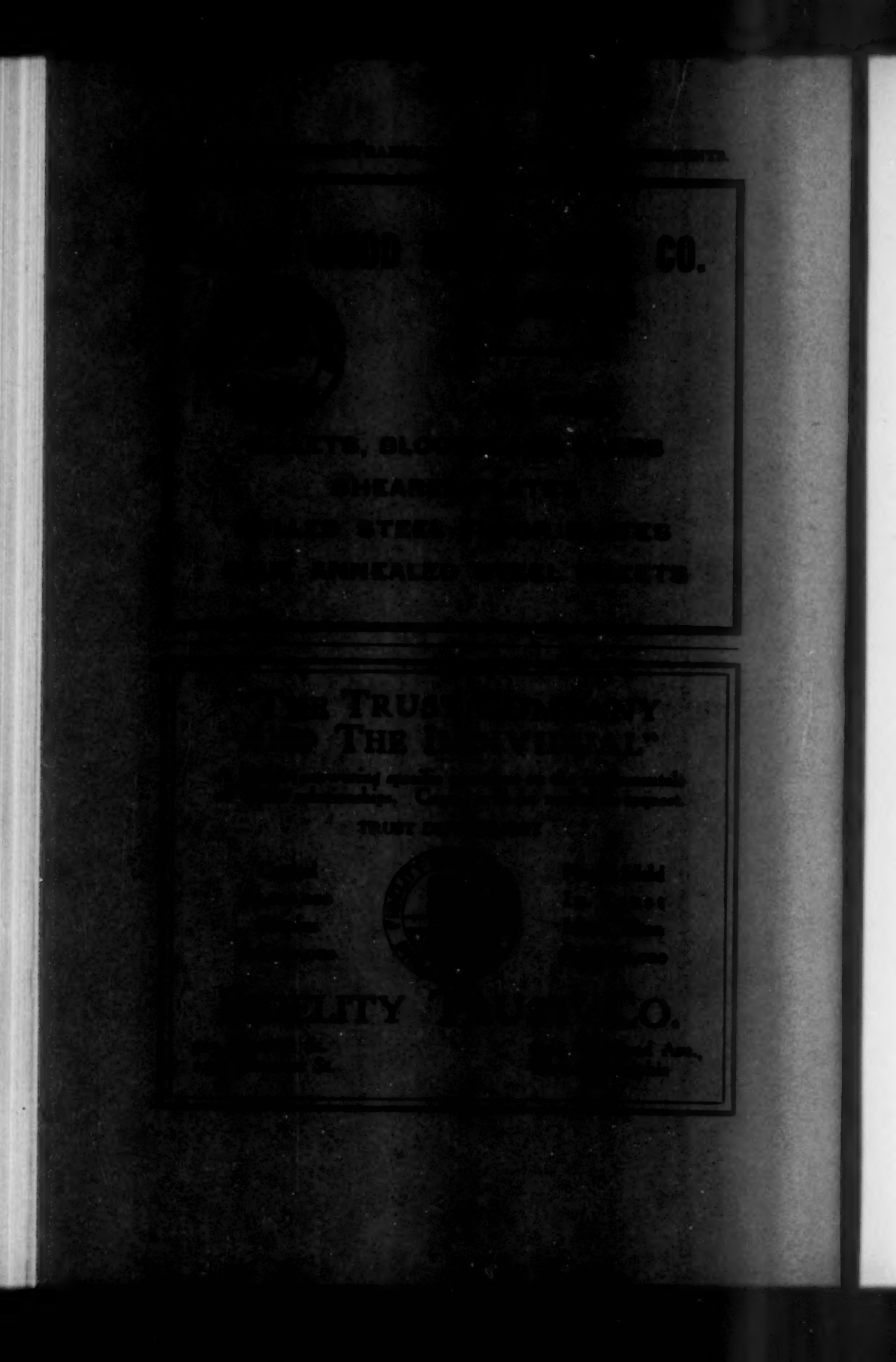

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MOLECULAR ATTRACTION AND MOLECULAR COMBINATION.*

BY

O. MAASS, Ph.D.

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INTRODUCTION.

ONE of the present aims of science is to explain the properties of matter in terms of the properties of its basic constituents, the proton and the electron. The problem of the numerical electron-proton content of the atom of any element has been solved. The physicist and chemist are now engaged in attempting to arrange protons and electrons into combinations such that the fundamental properties of the protons and electrons, expressed, for example, by a modified inverse square law of attraction, give the resultant properties of the atoms of the various elements. One of the most important of the resultant properties is the field of force which gives rise to the attraction existing between atoms of the same or of different species. The result of this attraction is the formation of molecules with a consequent neutralization of the greater part of the field of force. Complete neutralization never occurs. The molecule, as such, is left with a residual force of attraction, and this paper deals with some of the experimental methods by means of which the influence of these forces can be detected and their relative magnitudes estimated.

The subject of molecular forces is a large one and in this case is confined to the narrow field of investigation in which experi-

* Presented at a meeting held Thursday, March 6, 1924.

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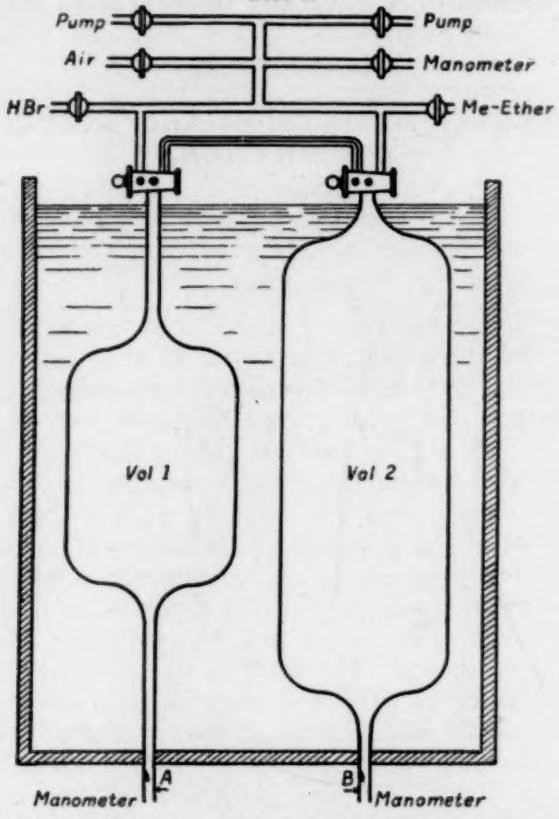
mental data were collected in the physical chemical laboratory of McGill University. It is proposed to make a few preliminary observations with regard to the nature and distribution of molecular forces in the molecule, and then to discuss the three series of investigations concerning: (1) Physical properties, (2) molecular

FIG. 1.



compound formation, (3) velocities of chemical reactions, by means of which information on this subject can be obtained. Where it is necessary for the clarity of presentation, the details of the experimental methods will be given.

ORIGIN OF MOLECULAR FORCES.

The atom of any element consists of a positive nucleus surrounded by a known number of electrons. With the principle that "any system will take up a configuration involving minimum

potential energy" as a guide, it follows that atoms will form molecules, and molecules in turn will act upon one another in such a way that the distribution of positive and negative electricity will be most symmetrical. In the case of elements like the inert gases, where the number of electrons is such that a very symmetrical space distribution is possible, the external field of force is found to be small, as shown by their inability to form compounds. Hence it has been suggested that the field of force originates in the resultant electric force of the positive and negative charges rather than in the magnetic force due to the motion of these charges around orbits within the atom. Furthermore, since the atom as a whole is electrically neutral, resultant electric forces can only come into play close to the molecule. This is in agreement with the well-known rapid falling-off of chemical force with the distance, which obeys an inverse distance law involving the fourth or greater power. On this basis of the electrical origin of the external force a hydrogen atom which is necessarily unsymmetrical will combine with another unsymmetrical atom of its own or of another species to form a molecule. When this other atom is a chlorine atom, formation of the halogen hydride molecule results in a decrease of potential energy. This decrease is much smaller if two hydrogen atoms combine with one another. The hydrogen chloride molecule is a polar molecule because the distribution of positive and negative electricity in it is such that, as J. J. Thomson puts it, "the centres of gravity of the positive and negative electricity do not coincide." The polar molecule can therefore cause a more uniform distribution of electricity by uniting with another molecule. Definite compounds, which may be termed molecular compounds, can thus be formed between two polar molecules such as ammonia and hydrogen chloride. Molecules may furthermore cause polarity in one another. This phase of the subject is to be discussed briefly in the conclusion as it will be easier to do so in connection with the experimental data.

PHYSICAL PROPERTIES AND THEIR RELATION TO MOLECULAR FORCES.

The magnitudes of the physical properties, melting point, surface tension, Van der Waal's "a," are governed by the molecular forces. The larger the relative values of these constants, the greater are the molecular forces. Melting point can be interpreted as the temperature where the molecules are anchored to

definite positions in space relative to one another, that is, where the molecular force of attraction is strong enough to prevent translatory and rotational movement due to their kinetic energy. Surface tension of a liquid is due to the differential force of attraction on the molecules near the surface of the liquid at low vapor pressures, there being a larger number of molecules below than above the surface layer. The critical temperature is the temperature at which the average kinetic energy of the molecules is just sufficient to permit their escape from the main body of the gas under the condition of concentration least favorable for escape; that is, $T_c \propto \frac{1}{2}mx^2 = \int f dx$, where f is the differential force on the surface molecules. Van der Waal's "a" is similarly a measure of the difference of pressure registered on a manometer from the true pressure existing in the bulk of the gas.

In Table I a number of related compounds which have been examined are written down in a decreasing order of magnitude of the physical constants mentioned above. The substances chosen are ones in which the constitutional formula is well known and (except in the case of the triple-bond compounds) can be readily represented by the Lewis, Langmuir or Thomson atom.[1] Experimental determinations of Van der Waal's "a" have up till now been made only in a few cases, but where determined, the order is the same as in the critical temperature column.

TABLE I.[2]

Critical Temperature.	Surface Tension.	Freezing Point.
Ethyl alcohol	Ethylene oxide	Acetylene
Ethylene oxide	Acetaldehyde	Allylene
Acetaldehyde	Acetylene	Ethylene oxide
Methyl ether	Methyl ether	Ethyl alcohol
Allylene	Allylene	Acetaldehyde
Propane	Propylene	Methyl ether
Propylene	Propane	Ethylene
Acetylene	Ethylene	Ethane
Ethane	Ethyl alcohol	Propylene
Ethylene	Ethane	Propane

[1] J. J. Thomson, JOUR. FRANK. INST., **195**, 593 (1923); Lewis, *J. Amer. Chem. Soc.*, **38**, 762 (1916); Langmuir, *J. Amer. Chem. Soc.*, **41**, 868 (1919).

[2] Maass and Wright, *J. Amer. Chem. Soc.*, **43**, 1098 (1921); Maass and Boomer, *J. Amer. Chem. Soc.*, **44**, 1709 (1922).

The order of the compounds is by no means the same in all three columns. These columns represent for each substance, high temperature where the substance is a gas, intermediate temperature where it is a liquid, and low temperature where it is a solid. If the properties are really representative of molecular force of attraction the first conclusion would be that the force of attraction varies with the temperature, that is, with the molecular velocity. Although this is doubtless true to a certain extent, inasmuch as the violence of collision may influence the relative positions of the atoms in the molecules, there is another reason for the variation in the columns, namely, that the molecular force influences the molecules in two ways, first of all the attraction of the centres of the molecules, which tends to cause approach, and secondly the polarity of this force, which tends to orientate the molecules relative to one another. In the case of gases the first predominates, since due to the equilibrium between rotational and translational energy the rotation of the molecule may be looked upon as preventing orientation. This is not so in the case of the molecules in the surface of a liquid. Langmuir's ingenious experiments have shown that polar molecules at the surface of a liquid are on the average orientated, so that the surface energies are representative of the attraction of the polar group for the main body of the molecules which are not orientated. This force diminishes with length of molecule or rather with the distance to which the polar group can get below the surface. In a solid all molecules are so completely orientated that they lose their identity to such an extent that the solid as a whole may be regarded as one molecule, and quite a different force will be required to pull the molecules into the liquid. That is the point which is to be emphasized. The critical temperature is then the measure of the attraction between the molecules at the surface of a gas and the main body of the gas, neither set of molecules being orientated. The surface energy gives the force of attraction between the molecules at the surface which are orientated and the bulk of the molecules which are not orientated. The melting point is a measure of the attraction between orientated molecules at the surface and the bulk of the molecules, which in this case are also orientated. All other physical properties similarly depend on one or the other of the above possible orientation combinations; thus Van der Waal's "a" and critical temperature, latent heat of evaporation and surface

tension, tensile strength of a solid and melting point, are in a broad sense interchangeable in Table I. Taking these facts into consideration in each column, examination of the positions of the substances relative to one another is in qualitative agreement with the polarities deduced from their constitutions.

In general though, taking a large number of different substances, those which come near the top in one list come near the top in another. This applies particularly to those which are not decidedly polar. The critical temperature and Van der Waal's "a" are the best measure of the total attractive force.

These physical constants are a measure of the attraction existing between molecules of the same species. There next comes the question of the attraction existing between two different species. One method to detect this is to measure the pressure changes which occur when two gases are mixed, and as it is easier to discuss this in connection with definite experimental data a few words about the method of measurement are desirable.

Two glass vessels (Fig. 1) are placed in a thermostat and each connected at the bottom to a tube forming one arm of a manometer. The upper ends of these vessels are connected by two-way taps to tubing, which makes it possible to bring the vessels into communication with one another, to evacuate them and to fill them with any desired gas. When the mercury in the manometers stood at levels *A* and *B*, volume 2 was just twice volume 1. Thus after evacuating both volumes, volume 1 could be filled with air at atmospheric pressure and this air transferred into volume 2 by opening the proper taps and raising the mercury until it completely filled volume 1. The mercury could then be lowered out of volume 1 after closing the tap at the top and the process repeated. Then it was found that the mercury was exactly level at level *B* in both arms of the manometer attached to volume 2. In this way, by filling volume 1 first with a gas α and then with a gas β and forcing them both into volume 2, it could be determined whether the gases had any influence upon one another. Thus if there is an attraction between the molecules of the two different gases one would expect a contraction in volume, or, since the volume after mixing is made exactly equal to the sum of the volumes before mixing, one would expect a diminution in pressure. The attraction of a molecule for its own kind must,

of course, be taken into account. Table II shows the results obtained for a number of mixtures.

In column one are given the gas mixtures used. Column two shows the pressure of the mixture, p, minus the original gas pressure of 760 mm. Column three shows this calculated pressure on the basis that the gases do not affect one another. Column four shows the difference between the measured and calculated pressures. A word of explanation is needed about the values contained in column three. The gases when mixed have partial

TABLE II.[3]

Temperature, 24 degrees; Initial Pressure, 760 mm.

Gases.	$p - 760$.	Calculated Pressure.	Difference.
$H_2 - He$	0.1	$0 + 0 = 0$	+ 0.1
$H_2 - CO_2$	1.1	$0 + 1.1 = 1.1$	0.0
$H_2 - (CH_3)_2O$	3.4	$0 + 3.5 = 3.5$	− 0.1
$He - CO_2$	2.0	$0 + 1.1 = 1.1$	+ 0.9
$He - (CH_3)_2O$	4.1	$0 + 3.5 = 3.5$	+ 0.6
$CO_2 - (CH_3)_2O$	0.3	$1.1 + 3.5 = 4.6$	− 4.3

pressures of about 380 mm. But at this lower pressure each gas approaches more nearly the ideal gas, the molecules of the same species being further apart and hence the pressure is greater than that given by Boyle's law applied to the original pv. Thus it has been found by experiment [4] that the pressure of methyl ether when the volume is doubled falls only to 383.5, not 380 mm. The determination of this and the other values given in the table was carried out by a special method described elsewhere. It is sufficient to say here that the figures given are accurate to the last decimal place quoted. Now, turning to the table, helium and hydrogen are so nearly perfect gases that they obey Boyle's law at the temperature and pressure measured, hence, on mixing them, there was no change in pressure observed, showing, as would be expected, that they have no attraction for each other. Hydrogen and methyl ether, and hydrogen and carbon dioxide show an increase in pressure corresponding nearly to the calculated pressure change, indicating that there is no attraction between these gases. However, that there is a slight attraction follows from a consideration of the results obtained when helium and carbon dioxide,

[3] D. M. Morrison (unpublished).

[4] Boomer and Mennie (unpublished).

and helium and methyl ether are mixed. In both cases there is a greater pressure registered than the calculated pressure. This result was so surprising that the experiments were repeated a number of times. One has to interpret them by assuming that the helium has the effect of causing a repellent force between the methyl ether molecules. The explanation is, however, easily found. If the methyl ether were present alone the pressure would, it is true, be only 383.5 mm. when the volume is doubled, but even at this lower pressure the ether molecules have an attraction for one another and a calculation shows that if this attraction were removed the pressure would be increased to 387.0 mm. The molecular attraction comes into play most strongly during collision and the presence of the helium molecules decreases the number of collisions between the methyl ether molecules. As the helium molecules themselves do not contribute to measurable attraction the partial pressure of the methyl ether is greater than if it occupied this volume alone. In the case of the carbon dioxide and methyl ether mixture, the magnitude of the negative value in the difference column shows that the attraction between methyl ether molecules and carbon dioxide molecules is practically the same as that which each has for its own species.

MOLECULAR COMPOUND FORMATION.

In the manner described above, the attraction between two types of molecules can be detected. When methyl ether and a halogen hydride [5] are mixed together, a very pronounced diminution in pressure takes place. Table III shows the diminution in pressure which occurs.

TABLE III.

Temperature.	Initial Pressure HCl.	Initial Pressure $(CH_3)_2O$.	$p - 760$.	Pressure Mixture Calculated.	Pressure Mixture Found.
18.8°	756.0	756.0	−42.5		713.5
	573.4	573.4		547.8	547.5
	382.9	382.9		368.8	369.2
9.2°	758.0	758.0	−55.8		702.2
	557.0	557.0		524.7	524.4
	378.7	378.7		362.65	362.7
	218.4	218.4		212.70	212.5

The attraction as evidenced by the great pressure decrease is of quite another type from that evidenced by the mixing of carbon

[5] Maass and Morrison, *J. Amer. Chem. Soc.*, **45**, 1675 (1923).

dioxide and methyl ether. Here the attraction is so great that it is probable that the number of molecules is decreased by pairs actually combining according to the equilibrium equation—

$$(CH_3)_2O + HCl \rightleftarrows (CH_3)_2O.HCl$$

If this is so, the mass law should apply, and by varying the concentrations, that is, mixing the ether and halogen hydride at lower initial pressures, the resultant pressure can be calculated. There is good agreement between observed and calculated values and since the latter are based on the existence of compound molecules the existence of these in the gaseous state seems probable. Similar results were obtained with gaseous mixtures of hydrobromic acid and methyl ether.[6] In these cases the attraction between the two different species is far greater than the attraction of each species for itself. Actual orientation occurs between pairs even in the gaseous state, giving complexes which act as single molecules.

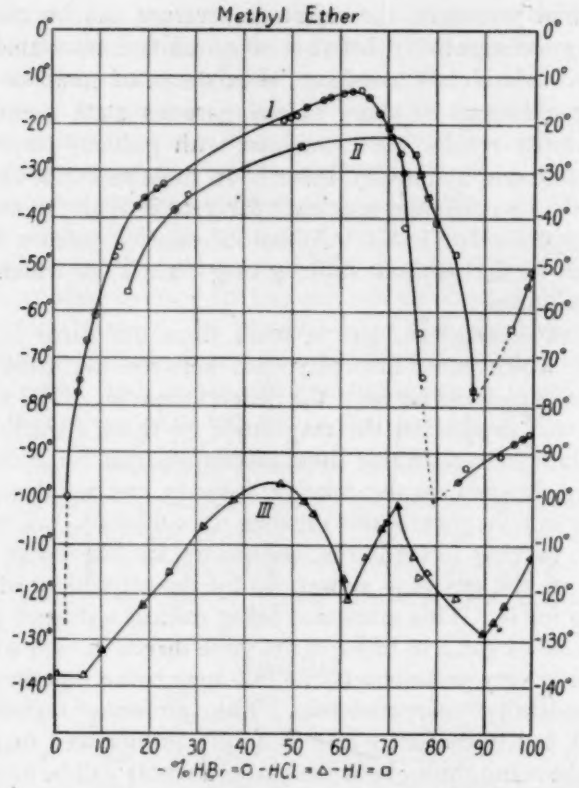
In a two-component gas mixture there are three forces of attraction which come into play, two between the same species of molecules and one between the different species. The total gas pressure will depend on the magnitude of these attractions and also on the extent to which these attractions can come into play. The latter depends on the relative volumes and numbers of the molecules which govern the number of collisions. A molecule of gas α, moving towards the manometer surface away from a molecule of the gas β is slowed up by the attraction which the latter has for it. This attraction being mutual will tend to cause the molecule of gas β to move in the same direction, and when this attraction is very pronounced, the two may move together, forming temporarily one molecule. The pressure registered is decreased, but in the latter case in a very pronounced manner, as the average result throughout the gas as a whole will be to decrease the number of molecules.

The marked attraction between the halogen hydride molecules and methyl ether has been investigated in another way, namely, by means of freezing-point curves. Fig. 2 shows the curves thus obtained.

[6] Maass and Morrison, *Trans. Roy. Soc. Canada*, III, **47**, May, 1923. Reference is made here to experimental work of Masson and Dolley, *Proc. Roy. Soc.*, A, **103**, 1923.

The phase rule application signifies that more than one eutectic in a two-component system proves the existence of compounds having melting points given by the maxima. In this instance the melting points of the compounds formed were much above the melting points of either component, showing that the methyl ether

FIG. 2.



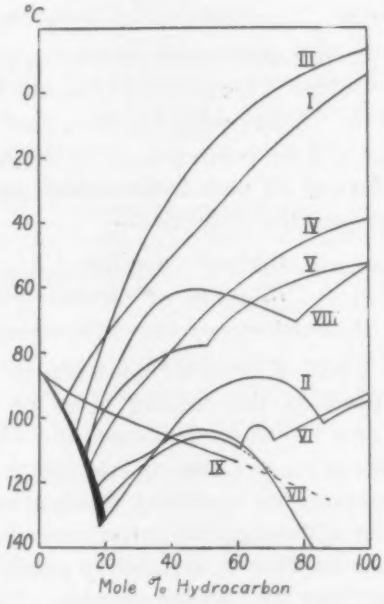
and halogen hydride molecules have a far greater attraction for one another than for molecules of their own species. Many oxygen compounds,[7] such as ketones and alcohols, have been examined in a similar manner and their attractions for the halogen hydrides proved by similar molecular compound formation. The name "oxonium compound" has been given to these complexes.

[7] McIntosh and Maass, *J. Amer. Chem. Soc.*, 34, 1273 (1912).

The physical constants of unsaturated hydrocarbons show that these compounds are polar, and their attractions for halogen hydrides have been examined by means of freezing-point curves. Fig. 3 shows the results obtained with the aromatic hydrocarbons.[8]

At first sight it would appear that some of them show an attraction for the halogen hydride and others do not. First, there

FIG. 3.



seemed to be no particular rhyme or reason in the results obtained. Para-xylene (Curve III), benzene (Curve I) and ortho-xylene (Curve IV) show the absence of molecular compound formation; meta-xylene (Curve V) shows the indication of a compound; mesitylene (Curve VIII) shows a pronounced compound, and ethyl benzene (Curve II), toluene (Curve VI) and propyl benzene (Curve VII) likewise show the existence of stable compounds. One generalization can be made—the lower the melting point of the pure hydrocarbon the more pronounced is the molecular compound formation. This is brought out in Table IV.

[8] Maass, Boomer and Morrison, *J. Amer. Chem. Soc.*, **45**, 1433 (1923).

TABLE IV.

	Melting Points.	
Para-xylene	+ 15.0°	No compound
Benzene	+ 5.4	No compound
Ortho-xylene	- 35.5	No compound
Meta-xylene	- 54.8	Indication of compound
Mesitylene	- 56.0	Compound
Ethyl benzene	- 92.4	Compound
Toluene	- 94.0	Compound
Propyl benzene	- 145.0	Compound

Consider a 50 per cent. molecular mixture of hydrocarbon and hydrogen bromide. This mixture is cooled down until crystallization takes place. From what has been said above, it follows that the crystals will be composed of hydrogen bromide, of a molecular complex, or of pure hydrocarbon, according to which of the forces between the molecules—

HBr ⟶ ⟵ HBr		I
HBr ⟶ ⟵ Hydrocarbon		II
Hydrocarbon ⟶ ⟵ Hydrocarbon		III

predominates. Force I remains constant in all the systems. Force III decreases as the melting point of the hydrocarbon decreases and Force II can predominate only when Force III has diminished sufficiently. To sum up, the benzene nucleus of the aromatic hydrocarbons has a polarity which attracts the hydrogen bromide molecule and when the attraction of the hydrocarbon molecules for one another is sufficiently small, the former will come into play to form a molecular complex. The question might be asked, what evidence is there for assigning the attraction to the benzene nucleus? This is answered by the experimental evidence which shows that hexahydrotoluol, which has even a lower melting point than toluene, does not form a molecular compound. Curve IX (Fig. 3) shows this. The benzene nucleus gives to a molecule a definite attraction for a halogen hydride which is, however, relatively small when compared with that of the oxonium compounds.

The acetylene linkage and ethylene linkage have also been examined from the point of view of their attraction for halogen hydrides. The freezing-point curves were examined and the results are given in Table V.

TABLE V.[9]

System.	Melting Point of Pure Hydrocarbon.	Compound Formation.
Triple Bond.		
Acetylene – HBr	– 80	None
Allylene – HBr	– 115	Pronounced compound
Double Bond.		
Ethylene – HBr	– 169	Slight indication
Propylene – HBr	– 185	Pronounced compound

The same arguments, when applied to the acetylene linkage and ethylene linkage, show that these have an attraction for the halogen hydride, but the actual freezing-point curves show this attraction to be smaller than that evidenced by the aromatic hydrocarbons.

EFFECT OF MOLECULAR ATTRACTION ON THE VELOCITIES OF CHEMICAL REACTIONS.

A few words about the experimental method involved in the freezing-point determinations of the last-mentioned systems will lead to the last section to be discussed, namely, the effect of molecular attraction on the velocity of a chemical reaction. Ethylene, acetylene, etc., are supposed to react with hydrogen bromide to form real chemical compounds—the alkyl bromides; thus:

$$C_2H_4 + HBr = C_2H_5Br$$

Freezing-point curves were determined by condensing known weights of these gases in a bulb by means of liquid air. The mixture was allowed to warm up till a homogeneous liquid formed and then the freezing point was determined. As in practically all cases, the liquid mixture was not allowed to warm up above –100°, no combination took place during the short time required to measure the melting point. This was proved by smashing the bulb and analyzing its contents for uncombined hydrobromic acid.

When the bulbs were allowed to warm up to room temperature and kept for some time, it was found that the acetylene and ethylene did not react with the hydrogen bromide. In the case of propylene a measurable reaction took place; in the case of allylene a rapid reaction took place. Propylene and hydrobromic acid[10] react to form alkyl bromides even at –78°. The rate of reaction

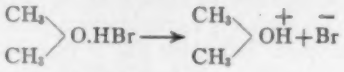
[9] Maass and Russell, *J. Amer. Chem. Soc.*, **40**, 1561 (1918); **43**, 1227 (1921).
[10] Wright (unpublished).

can be measured very accurately, so that results can be duplicated. There is considerable interest attached to the velocity of reactions at low temperatures, but here the point to be made is that ethylene does not react with hydrogen bromide whereas propylene does. All materials had been carefully purified and dried; there was, however, the possibility that the propylene contained a catalyst which enabled the reaction to proceed. Hence a mixture was made of 25 molecular per cent. propylene, 25 of ethylene and 50 of hydrogen bromide, and this was allowed to stand at room temperature in a sealed bulb. Subsequent analysis showed that none of the ethylene had reacted. Hence the rates of reaction of the hydrocarbons with hydrogen bromide are just in the same order as their tendency to form molecular compounds. Allylene and propylene form molecular compounds and have a much greater reaction velocity.

Where a chemical reaction is possible, mere collision between the molecules will not always result in a reaction. One has only to remember Baker's experiments with carefully dried oxygen and hydrogen. Where there is an attraction between the molecules, which presumably means that some molecules travel together a measurable time and are properly orientated, a reaction takes place without the necessity of the presence of a catalyst. The above are just a few examples of a number of reactions which have been examined in this way. The propylene and hydrogen bromide, freed from water by numerous pentoxide tubes, react. Whether exhaustive drying, such as Baker used, would prevent a reaction between them, has yet to be investigated. The point is that where a chemical reaction can take place the velocity of that reaction, in the absence of a catalyst, is dependent on the molecular forces of attraction.

Most of the compounds discussed can have their relative polarity predicted by the familiar static atom structure. In the case of methyl ether the distribution of positive and negative electricity is uniform about a central point. The structure, though, makes it possible for the CH_3 groups to move readily; the edges of the cube they have in common with the central oxygen atom, acting as hinges. This would occur on the approach of the positive end of a polar molecule toward the central oxygen atom. Thus, hydrogen bromide can be supposed to induce polarity in the methyl ether molecule. (The term "induced polarity" is not used here in the

sense in which it has been generally employed, but refers to group movements.) The subsequent ionization of this complex—



is in favor of this point of view.

CONCLUSION.

To sum up: The experimental determination of physical properties may be used to give an insight into the relative magnitude of molecular attractions existing between molecules when the orientation is taken into account. The molecular attraction between diverse species can be measured by gas mixtures, and if the attraction is strong enough molecular complexes result which can also be investigated by freezing-point curves; molecular attraction plays a part in governing the velocity of a chemical reaction. Rise in temperature increases the vibration of the atoms in the molecule which accelerates chemical reaction, but it seems plausible that in certain types of reaction orientation between molecules is necessary. As this can take place more readily if the molecules are moving slowly, reaction occurs between that very small number of molecules which, according to Maxwell's distribution law, have small translatory velocity and at the same time high vibratory energy of the atoms. This governs the temperature coefficient of the velocity of a chemical reaction.

The experimental work carried out so far is but the beginning, and as more data are accumulated some of the ideas put forward may prove to be wrong. However, they have been the incentive for undertaking these particular researches, and even if they do prove to be wrong, that will not take away from the pleasure which was derived from the carrying out of the experimental work, which has presented numerous difficulties.

On the X-ray Corpuscular Emission from Iron in a Magnetized and Unmagnetized State. G. A. CARSE. (*Proc. Roy. Soc. Edin.*, Vol. 53, Part III.)—In an endeavor to ascertain the ultimate cause of magnetism a number of experiments have already been made to compare the effects produced by magnetized and unmagnetized substances. Forman investigated the relative absorption of X-rays and " found that the absorption coefficient of iron for X-rays did not alter when the iron was magnetized in a direction perpendicular

to the beam, and that a small increase in the coefficient, amounting to five parts in a thousand for a field of 3500 gauss, was observed when the iron was magnetized parallel to the beam.

"Compton and Trousdale's experimental results indicated that in no case did magnetization influence the diffraction pattern.

"Compton and Rognley, as a result of their experiment, observed no change in the intensity of a beam of X-rays reflected from magnetite when the crystal was magnetized.

"Poole showed that when iron is magnetized there is apparently no large change in the total number of electrons emitted by the iron surface under the influence of ultra-violet light."

In the experiment described in the present paper a cube of soft iron was mounted in an ionization chamber with one of its axes vertical. Two opposite vertical faces of the cube were covered with copper. X-rays fell normally on one of the uncovered iron faces and the resultant emission of electrons was measured by the ionization produced in hydrogen. A magnetic field at right angles to the direction of the beam and sufficiently strong to saturate the iron approximately was thrown into action and the ionization was again measured. To eliminate the effect of the field on the corpuscles after their emission the same pair of observations was made with the rays incident on a copper face. After all allowances had been made the author draws the conclusion, "It would seem, as far as this experiment goes, that in the iron atom, either the part of the atom that turns does not emit an appreciable number of electrons, or the chance of ejection is not affected by the orientation." G. F. S.

Note on Tuning Forks. C. C. MASON. (*Jour. Scientific Instr.*, May, 1924.)—In the case of a fork rigidly supported there are three simultaneously vibrating systems, the support, and the two prongs. The two prongs may vibrate with different frequencies. The author measured the frequencies of the prongs of a badly balanced fork and found them to be 48 and 50, respectively. This fork did not seem to be especially poor except that it died down rapidly when held in the hand and struck. Set in vibration in this way a well-balanced fork will vibrate a considerable time because it is damped only by the air and, to a small extent, by elastic hysteresis. "It should be remembered that in a fork the two prongs vibrate in opposite phase, and it is only in the case of exact symmetry that the two bending moments at the base of the prongs are at every instant equal and opposite. It is not only necessary that each prong should have the same natural period, but the energy in each prong must be the same. When the two bending moments are not exactly equal, a bending moment equal to their difference is transmitted to the stem or handle of the fork."

The Cambridge Instrument Company has made a fork of elinvar with a coefficient of frequency of only .0000047 per degree C. A steel fork has a coefficient about twenty times as large. Unfortunately the alloy is both expensive and hard to work. G. F. S.

THE CONTROL OF RIVER FLOODS WITH SPECIAL REFERENCE TO THE MIAMI CONSERVANCY DISTRICT OF OHIO.*

BY

CHARLES H. PAUL, C.E.

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EARLY HISTORY.

PROBLEMS of protection from floods were encountered with the first occupation of river valleys in prehistoric days. The ancients exercised a measure of control over the Euphrates, the Tigris, and the Nile, by levees and by deflecting parts of the flood waters into depressions in the desert. These early works were tied up with irrigation works to a large extent, and it is hard to say which, in those days, was considered most important.

As civilization developed and property increased in value, the problem of flood protection has assumed more and more importance. European engineers, in the early days, studied methods of controlling the periodic overflow of their rivers, especially in the rich broad valleys of central France and Germany, and as early as the year 1711 retarding basins were used for flood control purposes. At that time, two rubble masonry dams were constructed across the valley of the Loire River in central France. The upper one, at Pinay, has its crest about fifty-six feet above low water. At river bed elevation there is an opening or vertical slot about sixty-four feet wide, reaching the full height of the dam. About four miles downstream is another similar dam built to supplement the controlling action of the first. These two dams, which have been in use for more than two hundred years, are still in operation, and records show that they have justified their existence during many large floods on the Loire River, particularly those of 1790, 1846, 1856, 1866 and 1907. Many other dams forming retarding basins for flood control have been built in France, Germany and Austria. Some of these are for flood control only, and some for the combined purpose of flood control and

* Presented at a joint meeting of the Institute and the Philadelphia Section, American Society of Civil Engineers, held Thursday, March 13, 1924.

storage. A list [1] has been published, giving some of the better-known retarding basin projects for flood control, in actual use, up to the year 1920. That list shows forty-five in Europe, one in India, and five in the United States, not including the works of the Miami Conservancy District.

The attempts at flood control by levees in China, dating back to ancient times, are too well known to require more than passing mention. Levee systems have been used in many places in Europe, particularly along the Seine, the Loire and the Rhone rivers in France. There are 322 miles of levees along the Po River in Italy, which was the first river in Europe to be leveed. There is no doubt that along with the early levee systems for flood control, a certain amount of channel enlargement was carried on to accomplish the same purpose. Here again, some of the channel improvement and levee systems were built exclusively for flood control, and some for the combined purposes of flood control, and channel regulation, or improvement for navigation.

In our own country the work of the Mississippi River Commission is the outstanding example of flood control on a large scale by levees. A combination of levees and dredging is a common solution of flood problems in many parts of the United States, and while retarding basin control had not been practised extensively in this country before the works of the Miami Conservancy District were built, still there were several relatively small retarding basin projects which had been in operation for a number of years.

THE 1913 FLOOD.

The flood of March, 1913, in the Miami valley, was not only the most severe of which there is any record in that valley, but, as regards damage, was the greatest that has occurred in the eastern half of the United States since the days of first settlement. A complete description of this flood and the damage which it wrought has been published in one of the Technical Reports of the Miami Conservancy District.[2] The flood was caused principally by hard rains which commenced on March 23rd, and continued with scarcely any interruption until the 27th. As a result of

[1] The Miami Conservancy District Technical Report, Part 7, "Hydraulics of Miami Flood Control Project," p. 49.

[2] Technical Report, Part I, "The Miami Valley and the 1913 Flood."

previous rains the soil was saturated, and this increased the runoff to the extent that during the latter part of the storm the runoff was 100 per cent. of the rainfall. The drainage area of the Miami River system is about 3600 square miles, of such size and shape that a heavy storm of intense rainfall may centre over it, and under certain conditions may result in a runoff practically equal to the rainfall, as was the case in 1913.

In the building of cities, railroads, and bridges, and in locating improvements near rivers, the usual high-water stages are taken into account. It has frequently been assumed that past floods, with perhaps a little estimated increase, are a reliable criterion of what may happen in the future. The fallacy of this reasoning for districts where records are available only over short periods, was well illustrated in the Miami valley during the flood of 1913. Levees and bridges had been built there to accommodate the largest flood that had occurred during the forty years or so that records were available. The water in Dayton during the crest of the 1913 flood stood about six feet higher than the tops of those levees. Not a bridge across the river was passable, many of them were washed out entirely. Nearly four times as much water came down the river as the leveed channel could carry. Large parts of the business and residential districts of the city were overflowed to depths up to twelve feet. Similar conditions existed in the other cities and towns throughout the valley.

The loss of life is not definitely known, but has been estimated at about 400. Property loss has been estimated at about $100,000,000. It is not easy to make a reliable estimate of loss in such cases. The indirect losses, from a disaster of this sort, are often fully as important as the direct losses. Subsequent deaths result from exposure and shock, or in other cases health is permanently broken. Depreciation of property values, interruption of business, loss of customers, loss of time and energy in cleaning out mud and water, are hard to translate into money values.

Many buildings were entirely destroyed; in Hamilton 200 residences were washed away and carried down the river; in both Dayton and Hamilton the flood was accompanied by fire, and many buildings were burned. Large areas of asphalt street surfaces were peeled off and carried away; tiled floors inside store

buildings were torn up and destroyed; sewers, gas mains and water pipes were filled with mud; in some places where the current was swift, streets were washed out several feet deep; in other places gravel and débris were piled up on the streets and in the yards to a considerable depth. Every railroad bridge, on a 100-mile stretch of river, was wholly or partly destroyed, and more than half of the highway bridges were also taken out.

The water of the river, during the flood, carried a heavy load of silt. As the flood waters broke in windows and doors, and flowed through buildings, the current was checked inside the rooms, and much of the silt settled to the floors or in the cracks. This process continued as long as the flood lasted. As a result, every crack and opening in floors, walls, or furniture, was filled with this sticky, slimy mud. On the floors of the houses, it lay from a few inches to a foot or more deep.

ORGANIZATION OF THE MIAMI CONSERVANCY DISTRICT.

Relief committees were organized in the different cities of the valley immediately after the flood, and plans for the prevention of future floods began to be formulated. Within sixty days after the flood had passed, and while people were still overwhelmed with the problems of their own personal losses, a fund of more than $2,000,000 was subscribed, in the City of Dayton alone, for the purpose of making investigations and studying the problem of flood prevention for the city. Each community worked independently at first, the thought being that the desired results could be accomplished by channel enlargement or relocation, and levee improvement. It was not long after the beginning of a systematic study of the problem, however, that it became apparent that channel improvement alone, to the extent required, was not practicable. The next thought was for retarding basins. Fortunately, there were suitable sites, along the upper reaches of the rivers, where retarding basins could be formed at not too great expense. It was apparent, however, that while channel enlargement by itself would not be sufficient, still a large measure of relief could be obtained at moderate expense by cleaning out bars and islands, strengthening levees and raising them a limited amount, improving channel alignment, and paving slopes where required. A certain amount of this work would give better returns for the money

spent than if retarding basin control were used exclusively. The final solution of the problem, therefore, was a combination of channel improvement and retarding basins, so adjusted as to capacities as to give the necessary control at the lowest cost.

This naturally pointed to the fact that one city alone could do little along this line by itself, and that it was a job for the people of the whole valley to undertake as a unit. Then followed problems of organization, securing public support, questions of legislation, adjustment of conflicting interests—problems in human engineering, which were no small part of the whole big job of securing the necessary flood protection. Under the Ohio laws there was no practical way for the people of the valley to organize for this particular purpose, and it became necessary therefore to enact legislation which would provide for such organization. The Conservancy Act of Ohio, passed in 1914, was the result of this effort, and paved the way for the organization of the Miami Conservancy District, which was effected soon thereafter.

ENGINEERING STUDIES.

In the meantime, while the necessary legislation was being prepared, the engineering investigations were going on and data were being collected and recorded, leading up to the studies for this comprehensive plan. Fortunately, the engineers were called in only a short time after the flood had passed, when high-water marks and certain other precise records were still obtainable. The vast quantity of data collected included typical cross-sections of old channels; levee profiles; cross-sections of the valleys at controlling points; surface slopes during peak of flood; size of bridge openings; time of flood crest at different stations; velocity of flood flow; runoff data; rainfall data; information on past floods; topographic surveys. The main object, of course, was to determine the peak flow, total discharge and high-water marks of the 1913 flood, and, by a study of past floods as related to rainfall and runoff conditions in the Miami valley and elsewhere, to determine what maximum could be set for future possible floods in this locality.

Corresponding studies and computations were started as soon as enough data had been obtained. These included studies of flow in open channels; determination of the value of "n" in the Kutter's formula, under various conditions; computations of peak

flow and total discharge, at various points, during the 1913 flood; study of shape, size and character of drainage area; determination of maximum possible flood; study and investigation of various methods of flood control; estimates of costs of various flood control plans. As soon as the retarding basin scheme became a possibility, other questions presented themselves, among the more important of which were the determination of the location, size and number of dams; tentative channel capacities through the cities; determination of height of dams and size of conduits; backwater effects and curves; spillway capacities; balancing of retarding basin capacities, outlet capacities, and channel capacities; and finally, a determination of the amount of public and private property affected; valuations of properties as to damages and benefits; preliminary estimates of cost.

PREPARATION OF PLAN, AND APPRAISALS.

There is no place, in a paper of this sort, for a discussion of the details of handling these various features of preliminary investigations. They are mentioned simply as a suggestion for those who have similar problems to undertake in the future. By the time the necessary legislation had been passed and the permanent organization of the District effected, the engineering studies had proceeded to the point where a complete plan could be outlined, indicating exact methods to be used in securing the necessary flood protection, together with volume and character of work required, types of structures, and estimates of cost. This so-called "Official Plan" was presented to the Conservancy Court by the Board of Directors of the District, as required by law, and was approved by the Court during the fall of 1916.

The next step was an appraisement of damages or benefits to property affected by the proposed construction. A Board of Appraisers, appointed by the Conservancy Court, prepared an appraisal roll of damages and benefits which was presented to the Court for approval and set for hearing during the summer of 1917. There were about 70,000 pieces of property affected. In assessing benefits, the value of the property and the extent of protection required were taken into consideration. For example, a property subject to flooding ten feet deep was assessed a larger percentage of its value than one subject to only three-foot flood-

ing. That is to say, each property was assessed in accordance with the degree of benefit to be received. The appraisal roll was approved with so few exceptions that the security for the bonds, as represented by uncontested appraisals, was ample to justify proceeding with the financing of the project and preparing for the construction of the works.

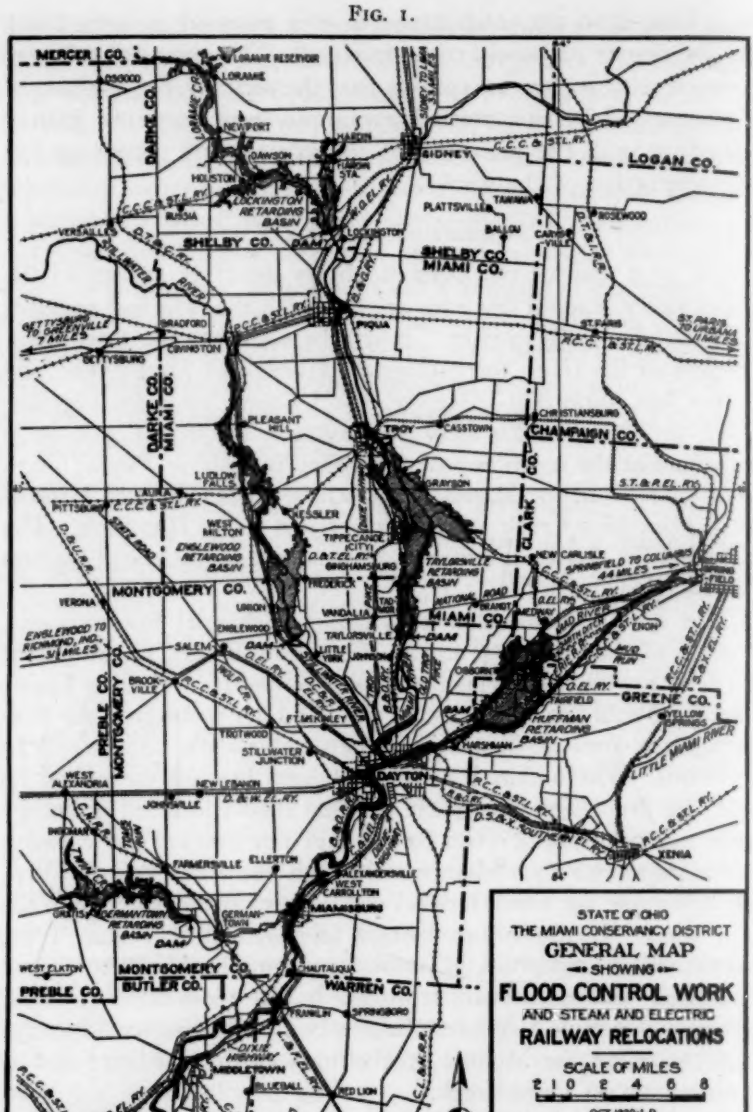
DESCRIPTION OF PROJECT.

Fig. 1, a map of the District, shows the river system of the Miami valley, and on this map are indicated the principal features of the flood control project. It will be seen that the three main branches of the river, the Stillwater, Miami and Mad rivers, and another less important tributary, Wolf Creek, all come together within the limits of the City of Dayton. Loramie Creek joins the Miami at the upper end of the valley just above Piqua; Twin Creek comes into the Miami River between Franklin and Middletown; Four Mile Creek joins the river just above Hamilton. The drainage area above Hamilton is 3600 square miles; above Dayton it is 2600 square miles.

The flood control plan provides for channel improvement, through all the cities and towns effected by floods, to the extent that it is economically feasible, supplemented by retarding basins which will hold back the crest of the flood, by restricting the flow through the dams, and backing up the surplus water temporarily in the basins. The outlets through the dams are not controlled by gates, but are designed of such size that their combined discharge under maximum head (full basin) will not overtax the capacity of the improved river channels through the cities below. Provision is made for a maximum flood 40 per cent. greater than the 1913 flood. Channel improvement is provided at Piqua, Troy, Dayton, West Carrollton, Miamisburg, Franklin, Middletown and Hamilton. Dams forming retarding basins are located at Lockington on Loramie Creek; at Englewood on Stillwater River; at Taylorsville on the Miami; at Huffman on Mad River; and at Germantown on Twin Creek.

In addition to building the dams and the channel improvement works, it was necessary to relocate about fifty miles of railroad lines, in order to get them out of the way of the dams and retarding basins. New locations satisfactory to the railroad companies were made at the expense of the District, under the general direc-

FIG. 1.


MERCER CO.
DARKE CO.
LORAINE RESERVOIR
LORAINE
NEW PORT
HARDIN
SIDNEY
LOGAN CO.
HOUSTON
DAWSON
FULTON STA.
LOCKINGTON RETARDING BASIN
LOCKINGTON DAM
PLATTSVILLE
TAWAWA
BALLOU
ROSEWOOD
VERSAILLES
RUSSIA
SHELBY CO.
SHELBY CO.
MIAMI CO.
PIQUA
ST. PARIS
BRADFORD
COVINGTON
TROY
CASSTOWN
CHRISTIANSBURG
CHAMPAIGN CO.
PLEASANT HILL
LUDLOW FALLS
LAURA
GRAYSON
MESSLER
WEST MILTON
TIPPECANOE CITY
ENGLEWOOD RETARDING BASIN
TAYLORSVILLE RETARDING BASIN
NEW CARLISLE
SPRINGFIELD TO COLUMBUS 44 MILES
MONTGOMERY CO.
VERONA
UNION
VANDALIA
MIAMI CO.
ENGLEWOOD TO RICHMOND, IND. 51 MILES
ENGLEWOOD
SALEM
TAYLORSVILLE DAM
LITTLE YORK
JAMESTOWN
OSBORN
MAD RIVER
GREENE CO.
BROOKVILLE
PREBLE CO.
MONTGOMERY CO.
FT. MCKINLEY
HUFFMAN RETARDING BASIN
YELLOW SPRINGS
TROTWOOD
STILLWATER JUNCTION
DAYTON
LITTLE MIAMI RIVER
WEST ALEXANDRIA
NEW LEBANON
JOHNSVILLE
XENIA
FARMERSVILLE
ELLERTON
SALEM-MORRISVILLE
WEST CARROLLTON
MIAMISBURG
GERMANTOWN RETARDING BASIN
GERMANTOWN DAM
WEST ELKTON
MONTGOMERY CO.
BUTLER CO.
PREBLE CO.
CHAUTAUQUA
WARREN CO.
FRANKLIN
SPRINGBORO
DIXIE HIGHWAY
MIDDLETOWN
BLUEBALL
RED LION
MIAMI RIVER
HAMILTON
MONROE
BUTLER CO.
WARREN CO.
DAYTON TO CINCINNATI 50 MILES
ACC. NO. 3855
STATE OF OHIO
THE MIAMI CONSERVANCY DISTRICT
GENERAL MAP
SHOWING
FLOOD CONTROL WORK
AND STEAM AND ELECTRIC
RAILWAY RELOCATIONS
SCALE OF MILES
2 1 0 2 4 6 8
OCT. 1920-L.D.
LEGEND
RETARDING BASIN
DAM.
RIVER IMPROVEMENT
RAILROAD RELOCATION

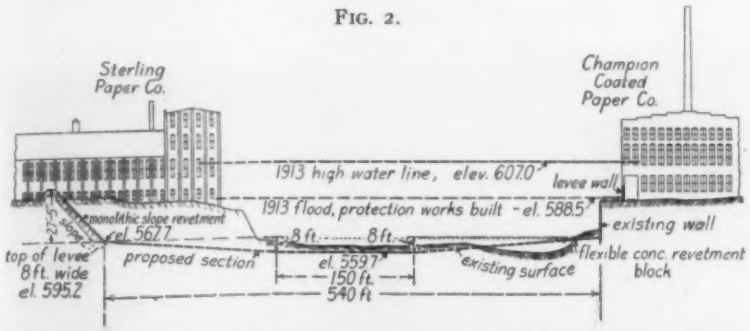
tion of the railroad companies. The old lines then became the property of the District and the rails and ties were salvaged.

Most of the railroad relocations were done by contract. The other work was done by a construction organization built up and equipped by the District for that purpose.

CHANNEL IMPROVEMENT.

The combination of channel improvement and retarding basin control permitted the channel enlargement to be confined to moderate limits through most of the cities. At Hamilton, however, the channel had been so severely encroached upon by industrial plants

FIG. 2.



Cross-section of channel at Hamilton, showing original conditions and proposed improvement. This view shows how the river channels were encroached upon in places by industrial plants. It shows the standard cross-section of improved channel, with a standard levee at the left and a retaining wall at the right, where space for a levee is not available. The two heavy dotted lines show the net effect, at Hamilton, of the flood control work.

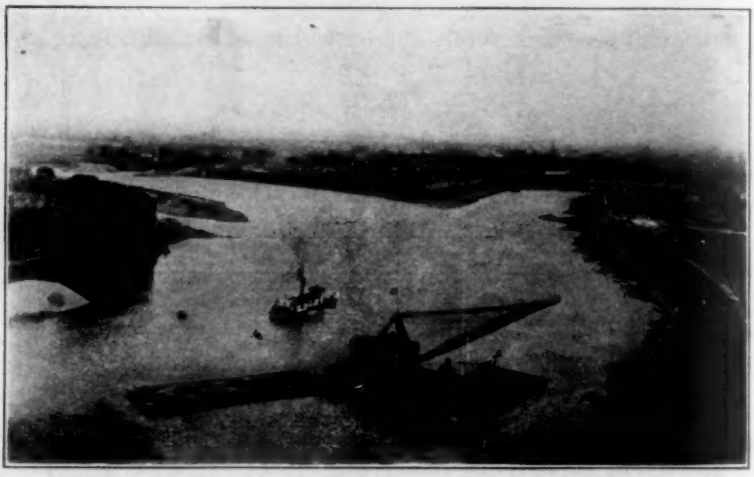
that a considerable widening was unavoidable. This work at Hamilton involved considerable property damage. This is illustrated by Fig. 2, which shows a restriction of the channel by two paper mills on opposite sides of the river less than 450 feet apart. The peak flow at Hamilton, during the 1913 flood, was 350,000 second feet, and at this point the water was backed up to a depth of about forty-seven feet and stood above second floor level in both buildings. In providing for the improved channel it was necessary to purchase one of the mills outright, and increase the width of the channel materially, in order to provide the necessary relief. Fortunately there were not many places as bad as this.

Fig. 2 also shows the standard cross-section of the improved channel. It has a low-water channel about 150 feet wide, with flat slopes or beaches on either side extending out to the toes of

the levees. The low-water channel is located in the centre where the river is straight, and near the outside of the bends where the channel is curved. The side slopes of the levees are 2 to 1, and where necessary because of high velocities, the slopes are paved with concrete. In places where there is not room for the levee slopes, concrete retaining walls are substituted.

Dragline excavators were used on all the larger features of the work, not only in making channel excavation through the

FIG 3.



Floating equipment on channel work at Dayton. The dragline machine, mounted on a spud scow, loads the large scows which are towed to an unloading point near the waste bank, which in this case is the point of land at the junction of the two rivers. The other machine, on shore near the end of the concrete bridge, unloads the scows and places the material in the waste bank. This view shows also a section of completed levee at the right.

cities, but also in excavating for outlet structures for the dams, and in the borrow pit excavation for the embankment material at the dams. The District used twenty-one of these machines varying in size from the small machine having a 30-foot boom and ¾-yard bucket, to the larger machines with 100-foot boom and 5-yard buckets. These largest machines, by using a smaller bucket, can handle a boom as long as 135 feet. In many places the dragline machine placed the material excavated from the channel directly into levee. Where this could not be done with one throw, it was economical to move the material two or three times, with a dragline machine, between excavation and levee.

At Dayton and Hamilton, however, the channel excavation

was so much in excess of levee requirements that the large part of the excavated material had to be wasted. The nature of the channel at Hamilton was such that a construction track could be placed within the river channel, but out of danger of moderate floods. The waste material was loaded into 12-yard dump cars and hauled to waste banks by 40-ton standard gauge dinkey locomotives. At many points on the Dayton work, it was impracticable to place tracks within the river channel, as even a small rise would wash them out. It was possible, however, to use scows for transporting a considerable part of the waste material there. A part of the work was excavated by one of the large dragline machines mounted on a spud scow, and in other places the scows were loaded by a machine on shore. The loaded scows were towed to an unloading point near the waste bank, and were unloaded by another dragline machine which placed the material directly into the spoil bank.

On the channel improvement work at the various cities and towns, three general methods were required. First, that in which channel excavation is the essential or most prominent feature, as was the case at Dayton and Hamilton. Second, that in which the work is confined almost entirely to levee construction, as was the case at West Carrollton, Miamisburg, Franklin and Middletown. Third, a combination of the two, as at Troy and Piqua. At places where levee construction was the principal item, and where the channel excavation did not yield enough material to build the levees, the levees were usually built by dragline machines, the necessary material being taken from borrow pits alongside. In a few cases it was more economical to build sections of the levees by teams.

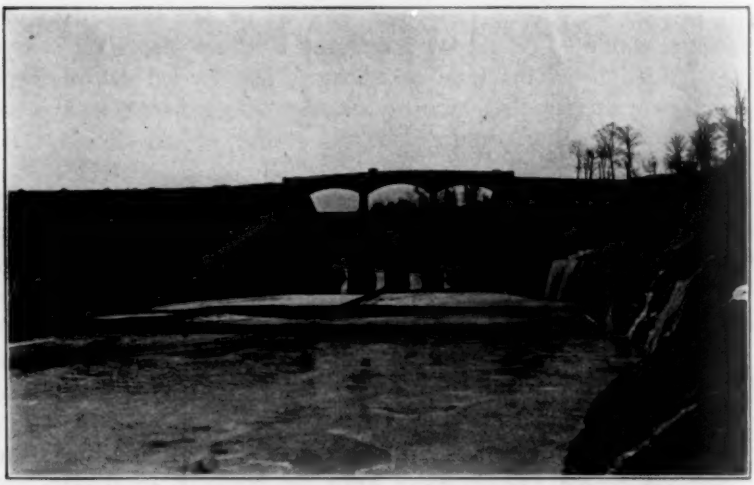
THE DAMS.

At each of the dams it was necessary to build a construction camp to take care of the required number of employees and their families, as there were no towns close enough to any of the dams to provide the necessary accommodation. These construction camps consisted of a number of cottages for the accommodation of employees and their families; bunk houses and dormitories for the laborers and mechanics; a mess house to accommodate several hundred men; a general store; club house; shops and warehouses; water supply and sewerage connections to each building; electric lights, and other conveniences of a well-managed up-to-date camp.

Preliminary investigations and examinations of foundation conditions dictated the selection of earth dams at all of the sites. Borrow pit investigations indicated that hydraulic fill dams would be practicable and economical, therefore hydraulic fill dams with massive concrete outlet works and spillways were determined upon at each of the sites.

The first important item of construction at each dam was the building of the outlet structure, or at least enough of it so that

FIG. 4.



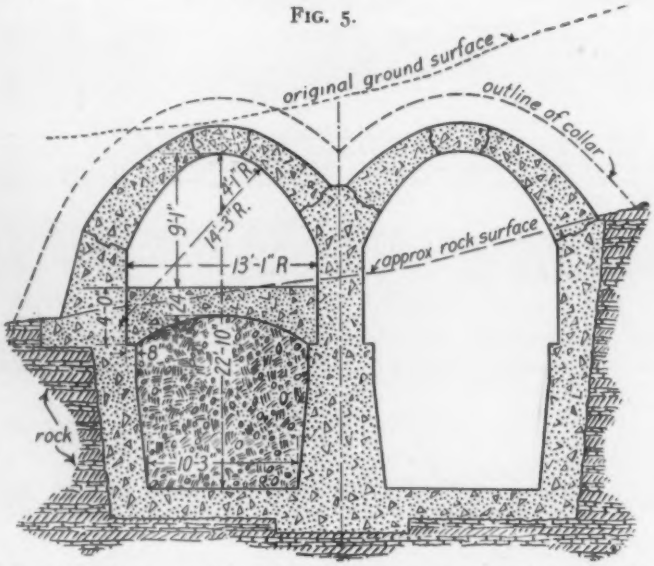
Outlet and spillway structure at Taylorsville. The side walls and floors were built first, leaving the gap unobstructed, to carry flood flows during construction. When the dam embankment had been nearly completed, the cross-dam was built between the walls leaving conduit openings of proper size at the bottom. The top of the cross-dam, left lower than the work on either side, forms the spillway. These conduit openings, at Taylorsville, are each fourteen feet wide and twenty feet high.

the river could be diverted from its old channel to permit the construction of the dam. Suitable rock foundations for the outlet and spillway structures were found at all of the dam sites. Two types of outlet structure were used. One type is illustrated by Fig. 4, which is an opening through the dam formed by two heavy concrete retaining walls facing each other with concrete floor between. That part of the structure, being built first, gave an ample waterway for floods during construction periods. After the embankment had been built up to the point where there was no further danger of overtopping in case of a flood, a cross-dam was

built between the two retaining walls and through the bottom of this cross-dam, at river level, the conduits for permanent flood control were constructed. The top of the cross-dam was placed twelve to fifteen feet below the top of the dams, thus forming the spillway.

Two of the dams, however, were so high that the construction of retaining walls to sustain the hydraulic fill embankment was prohibitive. At these places, therefore, twin conduits were used

FIG. 5.

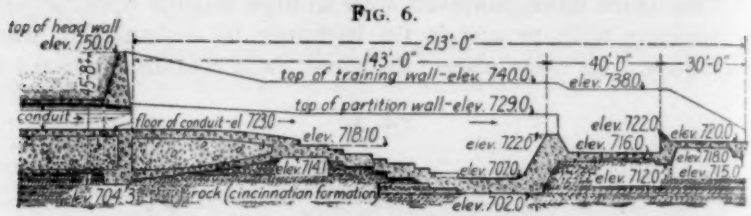


Cross-section of outlet conduits at Germantown dam. The opening at the right shows the original construction for handling flood flows while the dam was being built. When the dam embankment had been nearly completed, the bottoms of the conduits were filled in and floored over, as shown at the left, leaving the openings of proper size for permanent flood control. This also shows the location of construction joints in the conduit arches.

extending through the base of the dam at river-bed elevation. In order to secure additional capacity to care for floods during construction, these conduits were at first made deeper than was required, and as soon as the embankment had been completed, the bottoms of these conduits were filled in and floored over, leaving the opening of the size required for permanent flood control. Fig. 5 shows the details of this type of outlet structure, and illustrates how the additional capacity was obtained temporarily for stream control during construction. This illustration shows also the construction joints in the conduit arches, the interesting feat-

ure of which is the pair of joints near the crown of the arch. The "keystone" section between these two joints was poured after the concrete on either side had set, and this method proved effective in preventing cracks along the crown of the arch, which are so common with this kind of construction. At the two

FIG. 6.

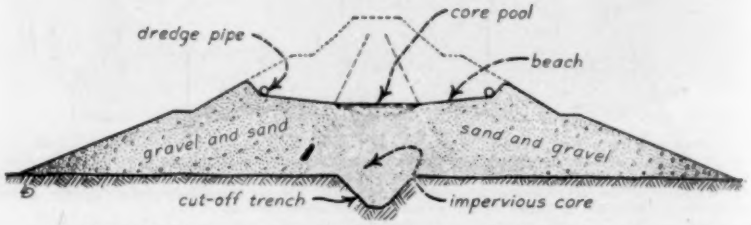


Stilling pool at outlet end of conduits. A deep pool, upstream from the main weir, forms a water cushion, which causes the hydraulic jump to form on the inclined floor. The main weir also helps to spread out the stream, and to block the formation of eddies and back currents. The second weir completes the spreading of the stream. Destructive velocities are effectively reduced by this means.

dams where these conduits were used, the spillways were separate structures.

At the downstream end of each of the outlet structures a stilling pool was built for the purpose of dissipating the energy of this swiftly flowing water (Fig. 6). This structure is so designed

FIG. 7.



The hydraulic fill process. The discharge pipe from the dredge pumps lays down the material along the outside slope of the dam. The coarse material remains in the outside. The fine sand and silt flow down the beach to the pool, where they settle through to form the impervious core. The dam is built up in layers varying in thickness from two to four feet at the different dams.

that the hydraulic jump or standing wave is formed within the limits of the concrete structure, and the floor and walls are made of sufficient thickness to withstand the action. The velocity is thus reduced, before it leaves the structure, to an extent that it will not erode the unlined channel below.[3]

[3] The theory of the hydraulic jump and back-water curves is discussed in Vol. 3 of the Technical Reports of the Miami Conservancy District.

At each of the dams a gravel washing and screening plant was erected for furnishing material for the concrete work. These plants were standardized and all parts were interchangeable. Suitable sand and gravel for concrete was found near each site. The material was hauled to the plant in dump cars and dumped into a hopper at track level, from which a belt conveyor took it to the top of the plant and delivered it to the screens. Wash water was delivered to the screens by a small centrifugal pump. The material

FIG. 8.

Placing hydraulic fill. The discharge line from the dredge pump is extended, length by length, as the layer of fill is brought forward. The coarser of the material remains near the outside slope, the finest particles being carried with the water to the core pool, where it slowly settles and consolidates to form the impervious core.

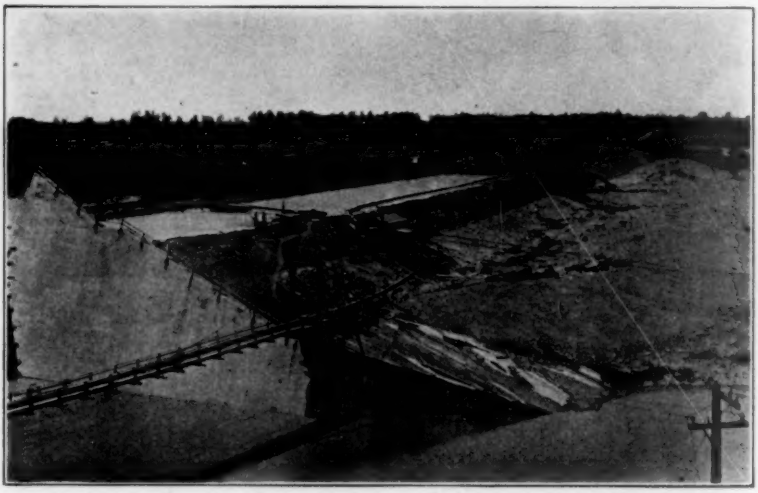
was separated into three sizes, sand, fine gravel up to 1½ inches, and coarse gravel from 1½ to 3 inches in size. Each of these sizes passed by gravity into separate storage bins. Oversize material could be wasted or diverted into the coarse gravel bins. In the heavy walls it was the practice to use oversize up to about 6-inch cobbles.

A one cubic yard mixer was placed in such position that the material from each of the three bins could be fed to the charging hopper by gravity through adjustable measuring boxes. Cement was stored in a shed near by and was brought to the mixing platform on small warehouse trucks as needed. The mixer

discharged into side dump cars, or bottom dump buckets on trucks, which were hauled to the work by 3-ton narrow gauge gasoline locomotives.

As none of the borrow pit material lay high enough to be sluiced direct into the dams, it was necessary at each of the sites to lift the material into the embankment by means of dredge pumps. In some cases, it was hauled to the dredge pumps in dump cars which were loaded in the borrow pits by means of dragline

FIG. 9.



Taylorsville dam under construction. The discharge pipe, in the foreground, takes the material from the dredge pump to its place in the embankment of the dam. Friction loss in these pipes varies from six to fourteen feet per hundred, depending on the quantity and character of the material handled. A booster pump was necessary to put the material out to the far section. The lower section of the dam is the closure section.

machines; in other cases it was broken down by hydraulic giants in the borrow pits and sluiced direct to the dredge pumps. Regardless of how the material was brought to the dredge pumps, the process from there on was practically the same at all of the dams. The hydraulic fill process automatically breaks up the borrow pit material into its component parts, and distributes the material in the dam in such manner that the coarse material is left in the outer portion of the dam, forming stable outer slopes, and the fine material is concentrated in the centre where it settles through a central pool or " core pool " to form an impervious core. The discharge lines from the dredge pumps are laid close to the

outer slope and parallel with it, and as the material is discharged from the end of the pipe, the gravel and coarse material drop there and remain, while the fines are carried on, with the water, to the central pool, where the core section is formed by slow deposition of this fine silt through water. Fig. 7 illustrates the process and also shows a typical cross-section of the conservancy dams.

Fifteen-inch dredge pumps were used at all of the dams. These pumps would handle single stones twelve to fourteen inches in diameter, but it was found that a number of these stones coming

FIG. 10.

Germantown dam completed, showing hydraulic jump in action during small flood. Velocity reduced from twenty-five feet per second at conduit outlets to six feet per second at outlet of stilling pool.

along together were likely to cause trouble, so it was arranged to reject, at the sump, all stones that would not pass through a seven-inch hole. This oversize was set aside for use as paving or riprap material.

PROGRESS.

Construction work began during the season of 1918. The intention was to push the work with all possible speed consistent with the economy, because flood protection for the valley was of vital importance. All the larger jobs were started at once, and as far as practicable all work was carried on by two 10-hour shifts.

The quantities handled were very large. Not counting the

railroad relocations, there were about 19,000,000 cubic yards of earth and rock to be moved for dams and channel improvements, and about 250,000 cubic yards of concrete work in structures at the dams, and along the improved channels. The one item of hydraulic fill at the dams amounted to more than 7,000,000 cubic yards.

Some very high progress records were made, especially in connection with hydraulic fill. At one dam, with one dragline machine in the borrow pit and one dredge pump in operation, an average month's work was about 60,000 to 70,000 cubic yards and in one month 91,500 cubic yards were put into the dam. At another dam with four giants in the borrow pit and two dredge pumps, the highest monthly output was 107,000 cubic yards. At another dam with three dragline machines feeding two dredge pumps, the highest monthly record was 180,000 cubic yards; a record of 150,000 cubic yards per month was not uncommon, and during each of three consecutive years more than 1,000,000 cubic yards were placed in that dam.

Every effort was made to so arrange the work that partial protection from flood would be secured at the earliest possible date, and that protection against a maximum flood would be assured as soon as could be. During the season of 1921 the work was in such shape that a repetition of the 1913 flood would cause only a limited amount of damage, and by the end of 1922, the work was ready to handle any flood that could possibly occur. On the tenth anniversary of the flood of 1913, the people of the valley were secure in the knowledge that flood danger for them was a thing of the past.

FIRST TEST OF COMPLETED WORKS.

Soon after the work had been brought to such stage of completion that a large flood could be handled, a storm occurred which gave the first real test. On April 11, 1922, a severe rainstorm began, which culminated on the 14th with very heavy showers. The rain was general throughout the valley; 1½ inches fell in less than two hours in many places; the total rainfall for the last twenty-four hours was 3½ inches, and this fell on saturated ground.

Under the old conditions, as they were in 1913, a flood stage of eighteen feet in Dayton, the old danger mark, would have been

reached or exceeded, and a bad flood scare would have resulted. Actually, however, with the flood control works in operation, the river at Dayton only reached a stage of 9.6 feet. This reduction in gauge height was due to both the river channel enlargement and the backing up of water behind the dams. All of the basins stored water, the maximum depth at two of the dams being approximately forty feet, with lesser amounts at the other three dams. At one dam the water in the basin was backed up for a distance of nearly five miles.

Everything worked out according to plan. The water was carried through the improved channels smoothly and swiftly, the familiar turbulent appearance in former floods being entirely absent. At all of the dams the hydraulic jump worked just as expected, and only a short distance below each of the outlets the water was flowing smoothly, and with moderate velocity.

There was such intense interest by the public, in the working of the system, that it was necessary to place traffic men at one of the dams to keep the crowds moving. The storms of April, 1922, were widespread throughout the country, and many communities suffered loss of life and property due to floods, but the citizens of the Miami valley viewed their own situation with complacency, feeling confident that future floods in their valley were absolutely under control. While it was apparent that the flood of April, 1922, was small compared with the maximum that the project was designed to handle, still it afforded a clear demonstration of the effectiveness of the works, and it was apparent that a much larger flood would be similarly handled with equal success.

The Number of Alpha-particles Emitted by Radium. H. GEIGER and A. WERNER. (*Zeit. f. Phys.*, Vol. 21, No. 3.)—When Geiger was working with Rutherford they calculated the number of alpha-particles emitted in a second by a gram of radium to be 3.57×10^{10}. Hess and Lawson in 1918 published 3.72×10^{10} as their determination of the same quantity. There is a difference of 4 per cent. between these values of a fundamental radio-active constant and in physics so great an uncertainty is intolerable. Geiger, now associated with Werner, turns again to the same problem, but he has a long experience in radio-active matters behind him and the resources of the Reichsanstalt at his command. In this investigation an alpha-particle is detected by the scintillation it produces on a zinc sulphide screen. Two possible sources of error present themselves. Does every particle assuredly cause a flash of light when it strikes the

screen, and is the observing eye always sure to see such a flash? To answer the first question 600 grains of the phosphorescing sulphide were spread out and subjected one by one to α-rays. Only 10 grains failed to flash when struck by a particle, and of these 8 were of small size, so that their chance of being struck and of affecting the count would be small. Moreover, the grains showed nothing to indicate that part of a grain might be sensitive and another part indifferent.

The possibility of flashes failing to be noted by the eye of the observer was remedied by having two persons count at the same time. Both registered electrically on the same strip of tape. It was found that from 8 to 12 per cent. of the flashes missed registration by an observer. The eye had to be kept in the dark fifteen minutes before beginning to observe and a thousand flashes were registered in a run, though with intervals for rest.

After all corrections were made the final value for the number of alpha-particles emitted by one gram of radium in one second is 3.40×10^{10}. Another determination of the number will be made by the use of an electrical means of detecting the particles.

G. F. S.

How to Show an Audience Foucault's Pendulum Experiment. F. HARMS. (*Physik. Z.*, Feb. 15, 1924.)—If a pendulum were swung from a support vertically over the North Pole of the earth, the earth would rotate beneath it, while it would continue to move in the plane in which its first swing was executed. To an observer on the earth unconscious of its rotation, the plane in which the pendulum oscillates would appear to change its position. In temperate latitudes the effect is not so striking as at the North Pole, but the rotation of the plane of the pendulum is still easily observable. Professor Harms, of Würzburg, by an attached thread pulls the pendulum to one side and holds it at rest while the wire just above the bob is focussed by a projecting lens on a distant screen, the plane of which is perpendicular to that plane in which the pendulum will move. A condensing lens illuminates the wire. The wire is burned, the pendulum begins to swing, soon the wire gets out of focus and its image on the screen ceases to be distinct. It reappears, however, when the pendulum returns to the extremity of its path at which it was released. But while the pendulum swung to and fro the earth was rotating and the plane of the motion of the pendulum seems to have changed with respect to its surroundings. By properly selecting the length of the supporting wire the amplitude of the swing, the focal length of the lens and the distance of the screen, it is possible to have the successive appearances of the image of the wire on the screen occur at points one cm. apart. Thus a person close to the screen can note a change in the position of the plane of oscillation after a single swing has taken place, and the change can be made visible to an audience after the execution of a few swings. G. F. S.

THE BEARING OF THE THEORY OF ISOSTASY ON SOME MAJOR GEOLOGICAL PROBLEMS.*

BY

WILLIAM BOWIE.

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SLOWLY the earth is yielding up her secrets to the steady but relentless march of science. Not many decades ago awe-inspiring theories regarding the earth were advanced, which made one fearful that we might at any moment be catapulted into the clouds by a volcanic eruption, swallowed up by the gaping earth, or that the internal fires would melt the thin rocky crust and thus end the world, as far as life is concerned.

We know better, now. Instead of having to draw conclusions from only what is seen—volcanoes active and extinct, earthquakes and the evidence of their past activities, warped and crumpled strata—we have wonderfully accurate observations which rival the best physical measurements of the laboratory.

The earth's dimensions have been determined with a high degree of accuracy by measurements by triangulation of distances and directions and the determination of latitude, longitude and azimuths from observations on the stars; the attraction of the earth at thousands of places has been measured by means of pendulums whose periods are determined to the ten-millionth of a second of time; the earth tides have been determined by Michelson and Gale with an accuracy almost inconceivable; ocean tides have been measured with extreme care and precision; the elastic waves from earthquakes have been recorded thousands of miles from their origin; and finally the variation of latitude has been determined by the most exact methods through more than two decades at especially selected stations.

With all these data we are able to show the weakness of some of the old theories relating to the earth, and the processes working to change the appearance of its surface.

Of course, the ideas that the earth is round, pear-shaped, or tetrahedral in form, or that it is a prolate spheroid, have all been abandoned for some time except by a few. By means of the

* Communicated by the Author.

geodetic data it was proved that the earth's surface, as defined by the surfaces of the oceans and of the water surface of imaginary sea level canals extended throughout all land masses, is an oblate spheroid with a meridional section almost a perfect ellipse. Nearly all of the earth's material has yielded under the gravitational and centrifugal forces as if it had no residual strength.

The centre of the earth, or that portion which can only be studied by indirect methods, is not a molten mass. This is proved by the elastic transmission of earthquake tremors through material at different depths, and by the observations for ocean and earth tides.

A volcano is not likely to burst forth at any place at any time. They probably will occur only in regions where mountains and islands are in course of formation or newly formed. Earthquakes will occur most frequently in areas where mountains and islands are in the process of formation or where erosion and sedimentation are most active. As erosion is going on from all exposed material and sedimentation is occurring in many places, and as there is horizontal movement below the earth's crust to adjust stresses set up by these disturbances of gravitational balance in the earth's crust, it cannot be said that any place is absolutely free from the possibility of an earthquake.

The earth's crust is floating on a yielding solid mass. The crust is solid but weak, is of the order of sixty miles in thickness, and yields to the gravitational negative and positive forces set up by erosion and sedimentation, respectively, just as the earth's materials yielded originally under gravitational and centrifugal forces to form an ellipsoid of revolution.

To long-continued stresses acting for periods of time reckoned geologically, the materials of the earth yield readily, while for stresses of short duration, seconds, minutes, days, or even a year, the earth's materials act as if they are as rigid as steel.

The dimensions and shape of the earth are not in any doubt, though they are subject to further refinement. Although the other characteristics of the earth mentioned above are not subject to direct proof, they result from processes of reasoning, accepted by all as sound, employed in the analysis of the accumulated accurate geodetic and other geophysical data.

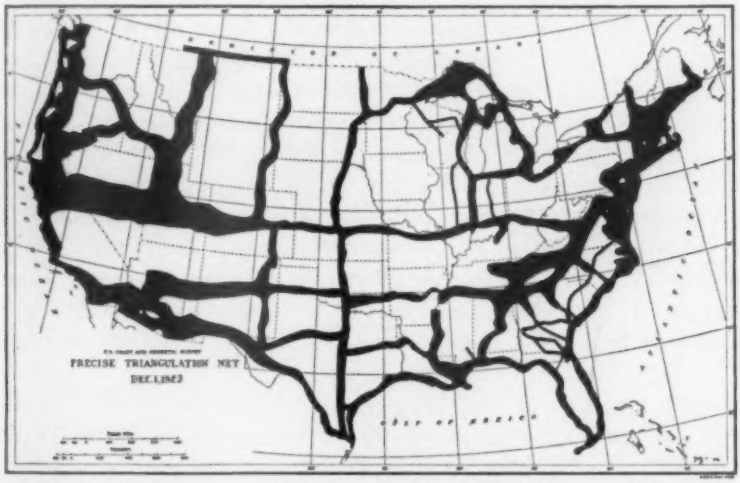
We cannot learn much of the early history of the earth from the physical observations and measurements and from the exposed

rocks, but we can from them interpret some of the history of the earth's crust for the past billion or so of years.

Barrell and others have estimated that the sedimentary age of the earth is something over one billion years. This estimate is derived from a careful study of the thickness of the strata of the several geological periods and the present rate of erosion from land masses.

Presumably before sedimentation began the earth's surface

FIG. 1.



These great arcs of triangulation and many hundreds of determinations of latitude, longitude and azimuth from astronomic observations in the United States, have been used to determine the shape and size of the earth and to investigate the isostatic condition of the earth's crust.

was too hot to allow water to fall and remain on it. The temperature at the beginning of sedimentation must have been below 100° C. To-day the average temperature of the earth's surface is probably somewhere between 10° and 20° C. The drop in temperature of the surface during the sedimentary age has therefore been somewhat less than 100° C. This is a fact of great importance, for one of the generally accepted theories regarding the cause of surface changes of the earth is that the nucleus of the earth has undergone great contraction from cooling and that the crust not having cooled the same amount has collapsed upon it. Is it probable that the inner material has cooled much more rapidly than that of the surface? No one knows, but it seems to be just

as logical to assume that they have cooled the same amount or that the surface has cooled more than the deeper materials.

With less than 100° C. of cooling of the earth's surface during the sedimentary age, it seems probable there could not have been such a greater amount of cooling of the interior as would have been necessary to account for so much contraction and crustal shortening, due to thermal and molecular changes in density, as the advocates of the collapse theory believe has occurred.

The geodetic data in the form of differences in the latitudes and longitudes, determined by astronomic observations and by direct geodetic measurements, and in the form of the values for gravity at many places widely distributed on the earth's land surface, enable us to prove that the sea level surface is a spheroid with only slight variations from a mathematical surface. Therefore, the materials of the inner portion of the earth must be of practically the same density for any given concentric shell. In other words, the variation of density along any radius of the earth is about the same as for any other radius. If it were not so, then the sea level surface could not be so nearly a mathematical surface. The gravitational effect of wide variations in density for different segments of the earth would cause great deviations from a regular sea level surface. This and the deduction that the earth is not a molten globe, but is a rigid solid to short period stresses, are all we know about the materials below the earth's crust. Any other properties and characteristics are based upon speculation. No one can tell whether at the centre there is metal or only greatly compressed rock. We have no way of telling what is the temperature of the earth's interior, though we think it must be high, judging from the rapidity with which the temperature increases from the surface to a depth of about one and one-half miles, the greatest depth to which borings have been made.

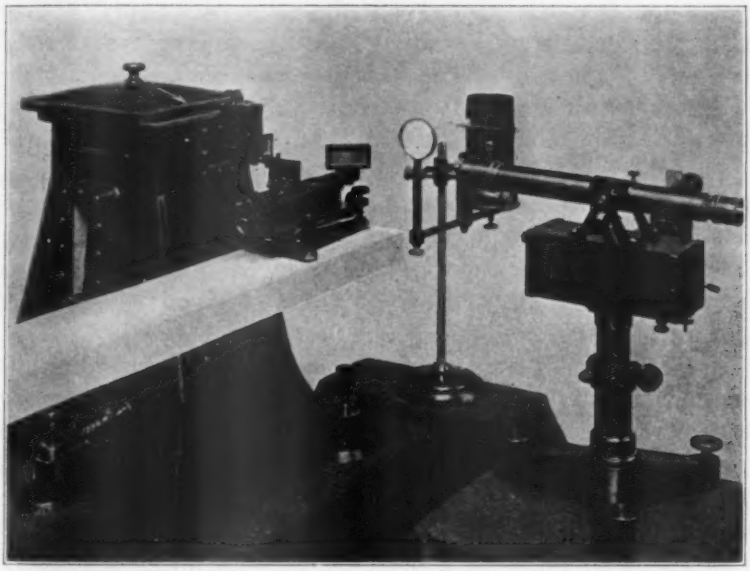
We are more interested in the outer portion of the earth, the crust, and its surface, and here the geodetic data help us.

The actual surface of the solid earth, as distinguished from the sea level surface, is irregular. The highest mountain peak is more than five miles above the ocean surface and the greatest depth of the ocean is about six miles. How can such great irregularities exist under the tremendous gravitational forces which tend to flatten out material? The analysis of the geodetic data indicates that these irregularities are due to varying densities

in the outer portion or crust of the earth, and there must be residual resistance of the crustal material to collapse which would fill in the depressions.

The anomalies or irregularities in the geodetic data are almost entirely accounted for on the theory that under each elevated region the crustal material is abnormally light and that under depressed regions the material is abnormally heavy. The crust

FIG. 2.



The values of gravity at many stations in this and other countries are used in the isostatic investigations. Differences in the value of gravity between the base and field stations are obtained from observations with the half-second pendulums swung in an air-tight receiver. The base station generally used throughout the world is at Potsdam, Germany, where observations were made for many years for the determination of the absolute value of gravity. The period of the pendulum is determined to one ten-millionth of a second of time with a probable error of about three ten-millionth of a second.

is resting on a yielding material. It exhibits the phenomenon of flotation. If the compensating deficiencies and excesses of density which balance the topographic irregularities are uniformly distributed below the elevated and depressed regions, they end at a depth of about sixty miles. No one knows how the deviations are distributed vertically, but for all our needs we may assume that they do take place within this distance and that the change from the resisting material of the crust to the yielding material below takes place at about sixty miles below sea level. It is

probable that there is no sharp break in the change from the unyielding matter of the crust to highly plastic subcrustal matter. There may be a layer of material ten, twenty or some other number of miles in thickness within which the material has varying degrees of plasticity. This may be called the transmission layer.

This flotational theory of the earth's crust was first advanced, though imperfectly, by Pratt [1] and Airy [2] about the middle of the last century. Dutton,[3] in 1889, set forth the theory more clearly and definitely and gave it the name of *isostasy*, derived from the Greek words meaning "equal standing" or "equal pressure." Putnam [4] made the first quantitative test of the theory in the nineties. He was followed by Hayford [5] and the writer [6] in this country, Burrard [7] and others in India, Klotz,[8] McDiarmid,[9] and Miller [10] in Canada, Helmert [11] in Germany, and Niethammer [12] in Switzerland. Other geodesists have discussed the theory but have made available little additional geodetic data for investigation. Many geologists [13] have written on the subject of isostasy, some of whom opposed while others upheld it.

It is impossible here to give even a brief summary of the many reports and papers which have been written during the past seventy years. In the following pages an attempt is made to show the importance of the theory of isostasy to the problems of geology.

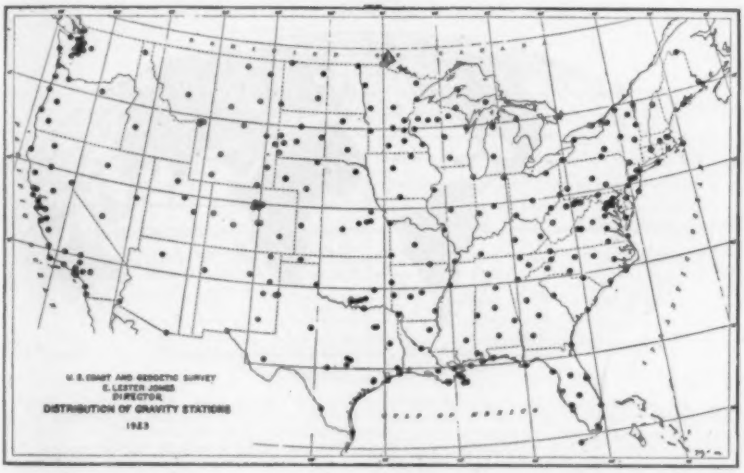
The theory of isostasy has been proved to be substantially true. Even blocks of the earth's crust of the order of magnitude of 100 or 200 miles square contain approximately the same mass as any other block of the same cross-section. Therefore, each block will exert very nearly the same pressure on an imaginary surface at some uniform depth, say sixty miles, below sea level.

A disc of surface material of 3000 feet or more in thickness and fifty miles or more in diameter is at least largely compensated by deficiency of material below.[14] By inference this probably applies also to like deficiencies of mass in the oceans. The isostatic balance obtains for all land areas tested, whether high or low in elevation. Areas of all geological formations are in balance, whether old, recent or intermediate. This applies to areas unloaded by erosion and those loaded by sediments. All of this being true now, is it not logical to conclude it has been true

throughout the sedimentary age of the earth, about a billion or more years? The author thinks that it is.

Since the earth's crust rises under erosion areas, and sinks under the sedimentary areas, and since even moderate-sized masses are compensated, it must be concluded that the crust is very weak to stresses of moderate amounts acting for long periods, say tens of thousands of years. Mountain masses are not held up as extra

FIG. 3.



More than three hundred gravity stations in the United States have been used in the isostatic investigations. Many of the stations were established to give a fairly uniform distribution while others were placed in positions to make geological tests or to show the horizontal distances to which the cause of large gravity anomalies extend.

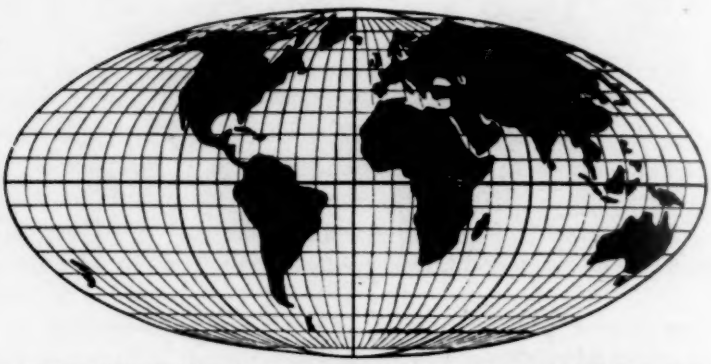
loads and certainly continents are not, nor are the ocean bottoms held down by the crust in an unbalanced condition.

As the earth's crust is weak and portions of it of moderate dimensions are floating more or less independently of each other on subcrustal materials, certainly stresses could not have been accumulated in it of such magnitude as to cause eventually world-wide crustal movements resulting in the upheaval of great mountain masses as extra loads. Nor could such stresses develop to the extent of causing portions of the crust to be pressed down into the subcrustal space, displacing heavier materials to balance the mass thrust upward.

Let it be assumed for the moment that the earth's crust is of such strength that it can hold up a mountain as an extra

load and that there exist tremendous stresses sufficient to force up a mountain mass. Then we should have the very anomalous condition that a rigid, strong crust can carry thrusts for thousands of miles to the buckled area, and yet undergo the tremendous distortion involved in shortening the width of the affected area which will be of only moderate length. It is believed that the collapse theory which holds that there can be an accumulation of forces sufficient to act through great areas and thrust up a moun-

FIG. 4.



The area of the earth's surface is about 197,000,000 square miles; of this about 56,000,000 square miles is land. The area of the United States for which isostatic investigations have been made is about 3,000,000 square miles. Other areas involved in the investigations total nearly the same amount. While only about one-thirtieth of the earth's surface has been used in this research, it appears safe to conclude that all the crust of the earth is in isostatic equilibrium.

tain system will have to be abandoned. Evidence and logic seem to be against it.

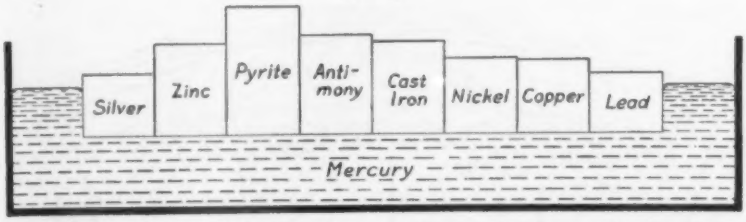
If the nucleus of the earth should cool faster than the crust and hence contract more rapidly, then on the isostatic theory the crust would simply thicken. The crust is too weak to be able to resist the tendency to collapse until the stress had accumulated to the extent postulated by some investigators. Assume that there has been no change in the crustal volume, then the inner radius of the crust will be that of the contracted nucleus, and its outer radius will have been lessened by an amount somewhat less than that of its inner radius, and hence the crust will be thicker than formerly. This reasoning is in conformity with the deduction that the earth's crust is weak enough to be in isostatic equilibrium.

There seems to be no world-wide acting force concentrating its effect in a single area of limited extent or in several such areas.

There is no outside force now acting which can have any marked effect on crustal movements (the sun and moon are the only near celestial bodies which can have any effect and their gravitational forces are only shown in the tides) and the interior of the earth has had billions of years in which to adjust any stress differences within its materials.

Do we not have to search for some force which acts locally, rather than regionally? The force which is constantly acting is

FIG. 5.



If blocks of metal of different densities but of the same mass were molded to the same cross-section and placed upright in mercury, they would sink to the same depth. Their lower bases will be in the same horizontal plane. The upper surfaces would stand at different distances above the surface of the mercury. This is a simple case of hydrostatic equilibrium.

gravitation, and this is continually being disturbed by *erosion* and *sedimentation*. Some portions of the earth's crust are being rapidly eroded and made lighter and other portions are made heavier by the deposited sediments. The isostatic balance is disturbed. The sedimented portions will be drawn down by gravitation, the eroded portion will be pushed up by heavier portions surrounding it, forcing yielding subcrustal material under the lightened area. In effect, the subcrustal material pushed away by the sedimented portion of the crust will move toward the eroded portion and the isostatic balance will be restored. There are many areas of rapid erosion on any continent and also many areas receiving sediments, therefore there will be no simple lines of movements in the subcrustal materials to restore the balance. That the balance has been restored is conclusively proved by the investigations based on geodetic data.

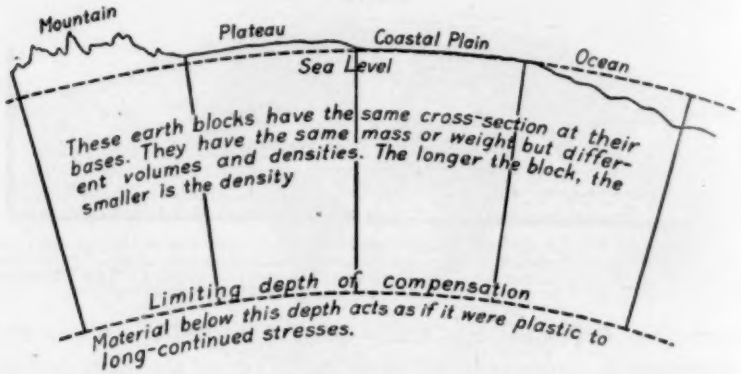
Mountains are found in areas which were formerly occupied by great masses of sediments laid down before the uplift. The uplifted materials are not extra loads and therefore they are due to an expansion of the materials of the crust beneath.

This must be true also of the great plateau masses which have

been uplifted without great distortion of strata and in some cases with the strata showing little or no distortion. This is a logical deduction from the fact that all areas are in equilibrium, whether high or low, of erosion or sedimentation, provided isostatic equilibrium has obtained throughout the sedimentary epoch of the earth's history, which is reasonable.

Let us summarize the conclusions regarding the crust and the subcrustal materials so far reached. The earth's crust is in

FIG. 6.


Mountain
Plateau
Coastal Plain
Sea Level
Ocean
These earth blocks have the same cross-section at their bases. They have the same mass or weight but different volumes and densities. The longer the block, the smaller is the density
Limiting depth of compensation
Material below this depth acts as if it were plastic to long-continued stresses.

If the earth's crust could be cut by vertical planes into blocks of equal horizontal cross-section, each block would have very nearly the same mass as each of the other blocks. The blocks exert the same pressure on the subcrustal material. The minimum cross-section of the block which may be in isostatic equilibrium is not known but is probably of the order of magnitude of 100 miles square.

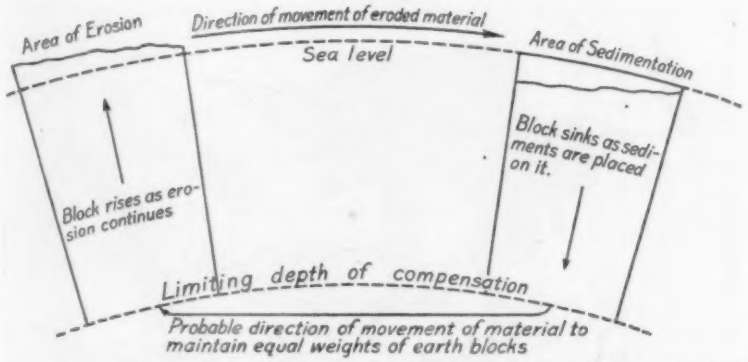
isostatic equilibrium. This equilibrium obtains for areas of all elevations. The crustal material rises under erosion. It sinks under sediments. The crust is solid but weak to gravitational disturbances caused by erosion and sedimentation. The subcrustal material in effect acts as a liquid and supports or floats a lighter solid; it moves horizontally to maintain the isostatic balance of the crust. Mountains and plateaus are raised by the expansion of the crustal material beneath them.

We are now confronted with the problem of discovering a cause, or causes, adequate to change the density of the material of the crust and form the mountain systems without having to resort to forces of world-wide activity or forces outside the earth.

A searching analysis seems to point to the influence of changes in temperatures. Whether these are adequate may never be proved. As sediments are deposited in beds tens of thousands of

feet in thickness the earth's crust beneath is forced down, each element of the crust sinking to a new and presumably hotter place. The temperature of the crust at any depth below the deepest borings will forever be unknown, but for the first mile below the surface the increase in temperature averages about 50° C. If 30,000 feet of sediments are laid down in any area the crust will sink almost an equal distance, and if the temperature gradient is the same throughout the crust each particle will be raised to a

FIG. 7.


Area of Erosion
Direction of movement of eroded material
Sea level
Area of Sedimentation
Block rises as erosion continues
Block sinks as sediments are placed on it.
Limiting depth of compensation
Probable direction of movement of material to maintain equal weights of earth blocks

The disturbance of the gravitational balance of the earth's crust by erosion and sedimentation seems to be the most important factor leading to changes in the configuration of the earth's surface. Material is moved over the surface by streams and rivers. This leads to movements within and below the crust as is indicated in the sketch above.

temperature nearly 300° C. greater than it had before subsiding began.

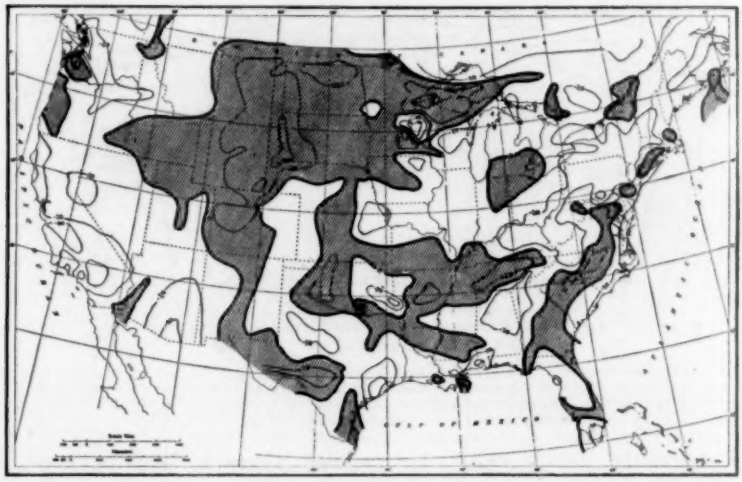
It has been stated by investigators [15] that the earth's materials are very poor conductors of heat, and that in spite of the fact that sediments of great thickness require great time for their collection, the surfaces of equal temperatures, called geo-isotherms, will go down with the sinking of the crust under the sediments. They will return to their normal depth only after the elapse of a long period following the cessation of sedimentation. Of course the geo-isotherms would rise somewhat as the sediments are being placed.

If all this is true then there would be a period of quiescence after sedimentation followed by the beginning of an upward movement as the rise of geo-isotherms heats the materials to temperatures at which molecular processes change their density and increase their volume. This change in volume would manifest

itself by a rise of the earth's surface above. There would be also some thermal expansion, but this would be inadequate to thicken the crust by more than about 3000 feet for a change of temperature of 300° C.

The sediments vary in thickness and the subsidence of the crust is not the same throughout. Some parts sink much deeper than others, while near the edges of the area covered by sediments the depression is very small. The critical temperature at which

FIG. 8.



A gravity anomaly is the difference between the observed and the computed or theoretical value of gravity. If the observed value is the larger, the anomaly is positive. The lines of equal anomalies were interpolated from about 340 stations in the United States and Canada. The shaded portions have positive anomalies.

molecular expansion occurs is therefore reached at different times in different places, and the resulting uplift is very irregular. While upward movement takes place in one part of the area other parts are inactive. During this irregular expansion the sedimentary strata become greatly distorted.

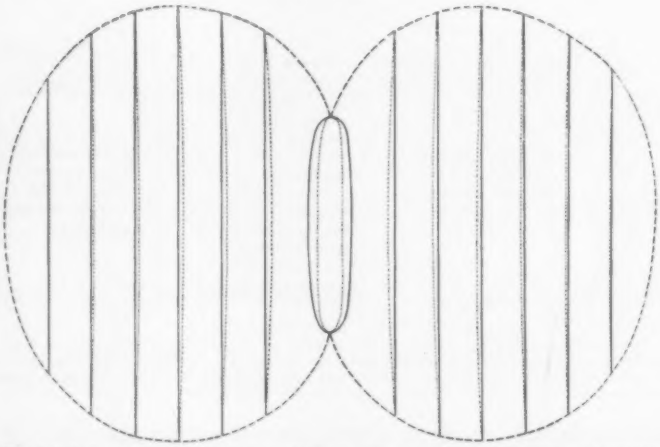
The crust to the sides of the subsided portion offers great resistance to the upward movement, causing the material to follow in its upward course the lines of least resistance. As one area is moved to a greater elevation than another, the gravitational stresses may cause the expansion to force material along inclined or even horizontal directions.

Only a portion of the distortion observed in any mountain area

is due to the original uplift. As the area becomes elevated, erosion begins. The removal of material lightens that portion of the crust, the isostatic balance is disturbed and subcrustal material is forced into the crust below and the material above is forced upward.

Tens of thousands of feet of material have been eroded from some mountain areas and equal masses have been brought into the lower part of the crust beneath. The upward movement occur-

FIG. 9.



The full line oval represents a mountainous area, previously an area undergoing heavy sedimentation. The full straight lines parallel to the mountain system, existing before uplift, would have been bent to their positions, shown by dotted lines, if the uplift had been due to horizontal forces acting in the crust from great distances. The shortening of the distance across the Appalachian system has been estimated as from twenty to some greater number of miles by advocates of the theory that the nucleus of the earth is shrinking and the crust collapsing on it. It is not probable that a crust which is weak enough to undergo the great distortion occurring within the areas shown in the dotted line ovals could have strength enough to thrust up great mountain masses. Besides, that theory makes extra loads of the mountains which is not in accordance with the proven isostatic condition of the crust.

ring with the erosion has in many cases exceeded the original upward movement.

The mountain area will be base-leveled eventually, for the mass of subcrustal material entering below will be of greater density and hence smaller volume than that of the eroded material.

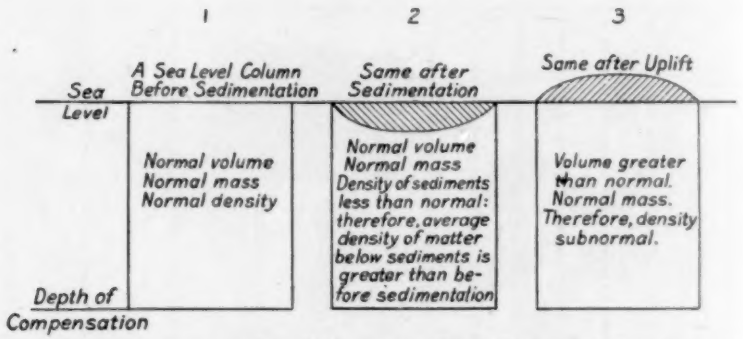
This uplift of the crustal material as erosion progresses carries it to colder regions, warping upward the geo-isotherms. After active erosion ceases there is probably a period of inaction followed by shrinking of the crust as the geo-isotherms approach their normal depths. Thermal and molecular contraction will

result, and the surface may sink below the sea level, in which case a new period of sedimentation would begin.

The area of some mountain systems has been below sea level and elevated several times. The Alps are a notable example.

The above-mentioned processes may not be the ones actually causing uplift and subsidence, but they are local in character and the very weak crust requires a force developed locally. We do not know just how molecular expansion and contraction occur, for we

FIG. 10.



Mountain systems occupy areas which were at a former time at or below sea level, while some areas now at low elevations were formerly occupied by mountains. Changes in density of crustal material, below the affected areas, must have occurred to change the surface elevations for the crust under all areas investigated is in isostatic equilibrium.

cannot duplicate, in our laboratories, the combined conditions of temperature, pressure, and time which exist in the crustal materials, but we do know that rocks having the same chemical constituents in the same proportions will have decidedly different volumetric densities. We may look for some enlightenment on this phase of our problem from the researches of such institutions as the Geophysical Laboratory of the Carnegie Institution of Washington and others. In fact, to attack the problems of the earth's crust successfully, we must bring in the physicist, the chemist and the engineer. The problems cannot be solved by only the geologist and geodesist.

Of fundamental importance is the work of Washington,[16] who has shown that igneous rocks have chemical elements present in different amounts in different portions of the earth's crust. As computed from the proportions of the several elements present, the densities of the rocks under continents are lighter than those under the oceans. The heavier elements are present in

greater amounts under the depressed areas than under the elevated ones. This leads us to infer that before the beginning of the sedimentary age the earth's surface was irregular in form and not an equipotential surface. Therefore when water began falling to the earth it was drawn to the lower areas and carried eroded

FIG. 11*a*.

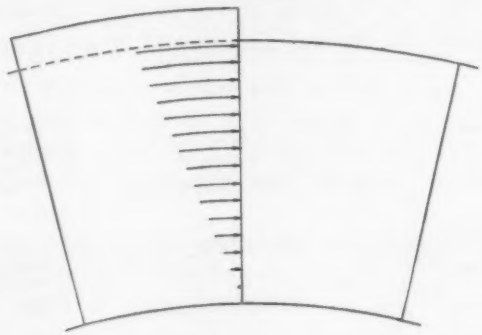
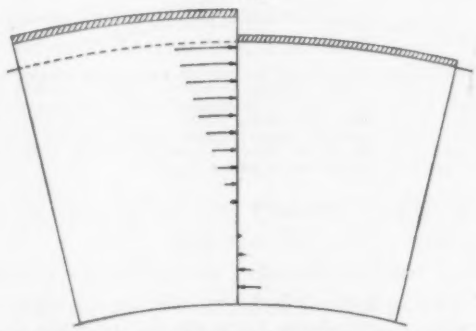


FIG. 11*b*.



For contiguous blocks of the earth's crust having different surface elevations, the stress differences are all toward the lower block (*a*). Should some material be rapidly eroded from the higher block and deposited on the lower one, the stress difference will be from the higher toward the lower block in the upper part of the crust. The direction of stress changes direction somewhat above the lower limit of the crust (*b*). These figures indicate that the horizontal movement, to restore isostatic equilibrium, occurs below the crust or far down in it.

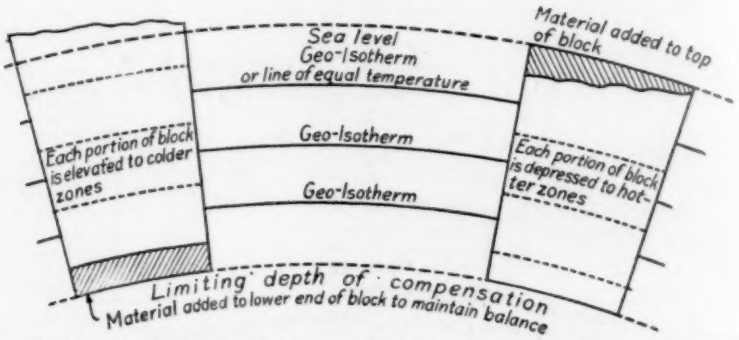
matter with it. No erosion could have occurred had there been no surface irregularities. The effect of the accumulation of large masses of water was to destroy the isostatic balance. The resulting adjustment lowered the basins and pushed up the elevated regions.

Mountains as we know them did not exist on the earth's surface prior to the sedimentary age. They are a result of

sedimentation and hence are formed at or near the margins of oceans and seas where sediments are accumulated to the greatest depths. Mountains are not formed where the crust is weakest, but where conditions are favorable to the expansion of crustal matter.

The work of Day and his staff in the study of volcanoes leads us to believe that volcanoes are due to local causes. The active ones seem to be only in areas of recent uplift or where uplift is still taking place. Volcanoes may be and probably are mere inci-

FIG. 12.


Material added to top of block
Sea level
Geo-Isotherm
or line of equal temperature
Geo-Isotherm
Geo-Isotherm
Each portion of block is elevated to colder zones
Each portion of block is depressed to hotter zones
Limiting depth of compensation
Material added to lower end of block to maintain balance

Erosion and sedimentation lead to great vertical movements of portions of the earth's crust. Crustal matter is forced down into hotter regions by the sediments and up into colder regions as the isostatic adjustment restores the equilibrium of the crust under erosion areas. The earth's materials change their temperature slowly. The geo-isotherms will be depressed under the sedimentary area and raised under erosion areas. As they again approach their normal depths the crustal matter will be greatly heated or cooled. Changes of density will follow, elevating some regions and depressing others.

dents to the processes involved in the decrease in density and increase of volume of crustal material.

It is probable that earthquakes are phenomena caused by local processes. This is a logical deduction from the result of investigations based upon geodetic data and from the theory of isostasy. Earthquakes probably are incidents to the up-movement of materials when mountains and islands are formed, to subsequent erosion, and to the sinking of the earth's crust as sediments accumulate. They are exceedingly rare in areas not subjected to the above three processes. These views seem to be in harmony with the results of investigations and discussions by Reid and Lawson.[17]

Some investigators who accept the theory of isostasy in its general principles are yet inclined to hold to the view that the forces which cause uplift operate from great distances. Keith [18] holds that uplift is the result of plastic matter moving within the crust

from ocean areas toward continents. A study of the accompanying diagrams, showing stress differences in the crust, seems to make this theory unsound. It seems to be reasonably certain that, though the crust is weak, portions of it of large dimensions are not like separate blocks of ice floating around in a pond of water under the influence of wind pressure. The ice is acted on from without. The portions of the earth's crust can only be greatly affected by forces developed within the earth itself. Erosion, sedimentation and consequent disturbed isostatic equilibrium seem to be the only processes with which we can work. If the crust of the earth is collapsing on a shrinking nucleus, this does not result in mountain forming. The crust under the oceans is not moving toward the continents, nor are the continents moving toward the oceans.

There has been much horizontal movement of strata, but it is believed it is due to local forces acting in the affected regions. During the uplift of an area to form mountains and to restore isostatic equilibrium, local horizontal movements of material, especially near the surface, will occur. The exposed strata have been interpreted as in favor of crustal shortening and hence of the action of world-wide forces. At best the evidence collected in the field is somewhat fragmentary. Strata cannot be followed without breaks throughout a mountain system, and it is possible to draw more than one conclusion from the observed evidence.

No attempt has yet been made on a large scale to harmonize the field evidence with the theory of isostasy, though this has been well done for restricted areas by Lee [19] and Nansen.[20]

The data accumulated in the field and laboratory by the geodesist and other geophysicists and by geochemists, combined with the vast amount of accurate geological evidence, seem destined to make possible a new and great chapter in the history of the science of geology.

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Death from Carbon Monoxide in Automobile Exhaust.—Widespread attention is being called to the dangers of automobile exhaust gases, and the following instance, reported in the *Bulletin of the Royal Academy of Belgium* (March, 1924), represents an unusual feature. Usually the fatal cases have occurred in closed garages, in which the engine has been running while someone was attending to the car. It has also been shown that even in the open street when this is crowded with motor vehicles a serious pollution of the lower stratum of the air may be produced. In the Belgian case, a night excursion by an autobus was planned. It seems that a peculiar form of excursion has been developed in Belgium. A party of a dozen or so are taken in a closed bus at night in such a way that they do not know the direction and after some miles of journey they are released and expected to find their way home. Those who arrive first at the point of departure receive prizes. The conditions of the excursion are of course that the bus should be well closed, so that no one can glean any information as to the route taken. We learn from the report that the car had a Ford motor. About a score of the contestants were packed in the bus, and a conductor and two assistants were on the outside. The passengers began the journey joyously singing and talking, but this soon ceased, and later some of the party hammered on the sides of the car, complaining of the lack of fresh air and of the heat. The persons in charge of the excursion hesitated to open any part, suspecting that it was merely a trick to get some idea of the neighborhood through which the bus was passing. On arriving at the destination, the conveyance was opened, and twelve of the party were found unconscious. All were removed to fresh air; eleven recovered consciousness, but one, a lad of seventeen, died. Those who could be questioned concerning the symptoms stated that the unconsciousness developed suddenly. Post-mortem examination of the boy showed the characteristic conditions of carbon monoxide poisoning. H. L.

PHYSIOLOGICAL STUDIES ON CEREALS.*

II. THE OCCURRENCE OF AMINO ACIDS AND POLYPEPTIDES IN THE UNGERMINATED OAT KERNEL.

BY

S. L. JODIDI, Ph.D.

(WITH THE COÖPERATION OF K. S. MARKLEY.)

IN THE first paper of this series it has been shown that the ungerminated kernel of wheat [1] (*Triticum vulgare*) contains polypeptides and free amino acids. It was quite natural to assume that such might also be true of the kernel of oats (*Avena sativa*). The importance of the oat crop as food and feed has caused its constituents, especially the nitrogen compounds, to be studied by various investigators. Concerning the proteins, it may suffice to mention that from the excellent work of Osborne [2] we know that the proteins originally present in the oat kernel are an alcohol-soluble protein, a globulin, and an alkali-soluble protein, and exceedingly small quantities of proteose and acid-albumin. The latter two, however, are very likely the result of transformations taking place during extraction.

According to Neumeister [3] the oat grain contains peptone also. Schulze and Castoro [4] state that the non-protein nitrogenous compounds constitute 0.125 per cent. of the dry seed, or 7.5 per cent. of the total seed nitrogen. Of these substances one was identified by Schulze as the base trigonellin,[5] while the presence of cholin [6] was indicated. Schulze [7] suspects that peptides may occur in seeds since the percentage of the non-protein nitrogen in substances isolated from various seeds is considerably smaller than the nitrogen percentage of the seed as estimated according to Stutzer's [8] method. He says, "Man darf vielleicht vermuten, dass unter ihnen auch Peptone und verwandte Körper (peptide) vorkommen."

* Communicated by Doctor Jodidi. From the Office of Plant Physiological and Fermentation Investigations, with the coöperation of the Office of Cereal Investigations, Bureau of Plant Industry, United States Department of Agriculture, Washington.

According to Czapek [9] the amide nitrogen makes up 2.18 per cent. of the total nitrogen in the ungerminated seed.

The aqueous extract of the oat kernel contains, in addition to the non-proteins mentioned, very little protein matter. It consists of small portions of an acid-albumin, a globulin and a proteose, according to Osborne.[10] In addition to those above, the writer has found amino acids and substances of a peptide character. While the ultimate object of the work will be the isolation of peptides present in the oat kernel, the way to identify polypeptides having been pointed out by Van Slyke,[11] it is to be borne in mind that thus far very few polypeptides were isolated from partially hydrolyzed proteins, namely, by Osborne and Clapp,[12] by Fischer and Abderhalden,[13] as well as by Levene in coöperation with Wallace [14] and with Beatty.[15] On the other hand, no polypeptides have, to our knowledge, ever been isolated from plant or animal materials. It seems safe to state that the isolation of peptides from the ungerminated oat kernel will require considerable time and labor. In the meantime the demonstration of the presence of peptides in the oat kernel, as outlined here for the first time, seems to be of sufficient interest to warrant the preliminary publication of the results obtained.

Briefly stated, our method of procedure was to remove from the dried alcoholic extract the proteins by successively treating the extract first with acetic acid and then with lead hydroxide plus lead acetate and filtering out the precipitates. This treatment, according to Hofmeister,[16] removes all protein matter including acid-albumin. The purified extract could be used for the estimation of the amino acid content. We next proceeded to remove the proteose and peptone by treating the filtrate from the proteins with phosphotungstic acid, which treatment, according to the work of Hirschler [17] in Kossel's laboratory and of Hausmann [18] in Hofmeister's laboratory, removes the two substances quantitatively.

The removal of protein, proteose and peptone was also effected by the employment of phosphotungstic acid alone. In the latter case, however, it is well to bear in mind that diamino acids, if present, are also thrown down. The filtrate from the phosphotungstic acid precipitate, as far as the NH_2 group is concerned, may contain amino acids only or also substances of a peptide

character. In the first case, suitable hydrolysis with acid should leave the amino acid content of the filtrate in question unchanged, while in the other case an increase in the amino acid content corresponding to the freed NH_2 groups of the peptides should take place. Hence, we hydrolyzed the alcoholic extracts of oats, freed from protein, proteose, and peptone, with 20 per cent. hydrochloric acid for twelve hours, since according to Fischer [19] the polypeptides behave very much like proteins and peptones with regard to their hydrolysis. In each and every case the extracts in question showed, on hydrolysis, a considerably increased amino acid content, proving that the extracts contain polypeptides. The details are given in the experimental part.

EXPERIMENTAL.

Four varieties of oats have been used in our experiments, one of which, the Iowar,[20] represents a pure-line selection of Sixty-Day, which was introduced into the United States from Russia in 1901. It out-yields practically all other varieties wherever early oats are well adapted. Victory, introduced from Sweden fifteen years ago, and Swedish Select are mid-season varieties which do well in the northern states, while Winter Turf is a fall-sown oat variety commonly grown in the South. The oat samples employed were clean, with the exception of Winter Turf, which was chaffy. All the determinations reported in this paper were made on samples comprising both hull and caryopsis and not on the caryopsis alone. In order to ascertain whether the several varieties have characteristic differences in their chemical composition, and to have a basis for the calculations, a number of estimations of their total, protein, and non-protein nitrogen, as well as of their ash, was made. The results are recorded in Table I.

Table I, in which the numbers represent the average of from four to eight analyses, shows that the total and protein nitrogen, when calculated to the oven-dried oats, is highest in Swedish Select, while in Iowar, Victory, and Winter Turf it gradually decreases in the order named. When, however, the protein nitrogen is calculated to the total nitrogen, it is found to be highest in Winter Turf, while Iowar, Victory and Swedish Select follow in the order named. As to the ash content, it is highest in Winter Turf, lowest in Victory, while the figures for Iowar and Swedish Select are between the two.

For all of the experiments reported, the oat samples were ground in an electric buhr-mill until all had passed through a 40-mesh sieve. In order to ascertain the minimum time necessary for a complete extraction of the oats with water, a number of flasks each containing 25 grams of flour and 400 c.c. of water were agitated by means of a shaker for a definite time at the expiration of which a measured amount of the clear filtrate was

TABLE I.

Percentage of Ash, of Total, Protein and Non-protein Nitrogen in the Ungerminated Oat Kernel.

Variety of Oats.	Where and When Grown.	Total Nitrogen.	Protein Nitrogen.		Non-protein Nitrogen.		Ash.
		Oven-dried Oats. Per cent.	Oven-dried Oats. Per cent.	Total Nitrogen. Per cent.	Oven-dried Oats. Per cent.	Total Nitrogen. Per cent.	Oven-dried Oats. Per cent.
Swedish Select (C. I. 134)	Grown at Dickinson, N. D., in 1920.....	2.59	2.30	88.65	0.29	11.35	3.25
Iowar (C. I. 847)	Grown at Iowa Agr. Exp. Sta., Ames, Iowa, in 1922.....	2.40	2.17	90.52	0.23	9.48	3.39
Victory (C. I. 560)	Grown at Dickinson, N. D., in 1922.....	2.02	1.82	90.21	0.20	9.79	3.15
Winter Turf (C. I. 435-4)	Grown at Arlington Farm, Rosslyn, Va., in 1922.....	1.50	1.36	91.03	0.14	8.97	3.72

oxidized according to Kjeldahl's method with the results recorded in Table II.

From Table II it is seen that the amount of nitrogen extracted in two hours is somewhat larger than that obtained in one hour, while the difference in the nitrogen extracted after two and four hours, respectively, is so small as to be negligible. For this reason all extractions were made uniformly by shaking the flour samples with water, for two hours, toluol or chloroform being used as antiseptic. In each case the extract, separated from the insoluble residue by filtration, was concentrated in a vacuum, the precipitates (largely proteins) formed during concentration were removed by

centrifugation and the supernatant liquid then finally evaporated to dryness. The dry residue was extracted with 80 per cent. alcohol, filtered, the alcohol distilled off, the remaining syrupy substance was taken up with hot water, heated to boiling, slightly acidified with acetic acid, boiled for two or three minutes, and filtered. The filtrate was now treated with freshly prepared lead hydroxide and some lead acetate, boiled and filtered. The clear filtrate was then concentrated under reduced pressure to 100 c.c.,

TABLE II.

Nitrogen Extracted from the Ungerminated Oat Kernel by Water.

Variety of Oats.	Duration of Shaking. (Hours.)	Of Filtered Extract Used for Kjeldahl. (C. C.)	Nitrogen Found in Filtered Extract.	
			Milligrams.	Air-dry Flour. (Per cent.)
(C. I. 134)	1	300	62.4426	0.333
	1	300	58.9261	0.314
	1	300	62.7508	0.335
	1	300	64.6982	0.345
		Average		0.332
Swedish Select	2	300	63.9136	0.341
	2	300	66.0992	0.352
	2	300	67.2760	0.359
		Average		0.351
	4	300	68.8872	0.367
	4	200	45.7287	0.365
	4	200	43.1088	0.344
	4	200	43.3890	0.347
	4	200	45.3784	0.363
		Average		0.357

of which two portions of 20 c.c. each were oxidized according to Kjeldahl's method, while 50 c.c. of the remaining solution were employed for the estimation of the amino acid content by the formol-titration method of Sörensen,[21] as applied by the senior [22] author. While it is realized that the method of Van Slyke [23] for the amino group determination is very much more accurate, it could not be used in this case for lack of the Van Slyke apparatus and for the further reason that apprehension was felt that the nitrous acid incidental to the latter method might split off some of the peptide nitrogen along with the nitrogen of the amino acids, as was pointed out by Fischer [19] (p. 52).

For the estimation of the acid amide nitrogen another portion of flour was treated as in the case of the amino acids. The purified

extract was finally concentrated *in vacuo* to 100 c.c., in two 20 c.c. portions of which the nitrogen was determined according to the Kjeldahl method. To 50 c.c. of the remaining solution hydrochloric acid was added to a concentration of 20 per cent. and boiled under reflux for thirty minutes. The hydrolyzed extract was now evaporated on the water-bath to dryness, taken up with hot water and distilled with magnesium oxide, the ammonia being received in an Erlenmeyer flask containing $\frac{N}{10}H_2SO_4$.

For the determination of the peptide nitrogen a third portion of flour was treated exactly as in the case of the acid amides with the difference that the hydrolysis lasted for twelve hours, instead of thirty minutes. The evaporated hydrolysate was now freed from ammonia by distillation with magnesium oxide, whereupon the residue was thoroughly extracted with boiling hot ammonia-free water, the extracts being concentrated under diminished pressure to 100 c.c. In two 20 c.c. portions of this the nitrogen was determined according to the method of Kjeldahl, while 50 c.c. of the remaining substance were employed for formol titration. Inasmuch as in this case the titration with formaldehyde yields both the nitrogen of amino acids and of polypeptides, it is necessary to subtract from this result the amino nitrogen found *before* hydrolysis in order to obtain the nitrogen of polypeptides only. The data secured are summarized in Table III.

Inspection of Table III reveals the fact that the nitrogen of amino acids, whose figures represent the average of at least four estimations, is highest in Swedish Select (17.39 per cent.), followed by Victory (15.08 per cent.), Iowar (14.87 per cent.), and Winter Turf (13.79 per cent.), when referred to the water-soluble nitrogen. As to the nitrogen of acid amides, its percentage is highest in Winter Turf (15.01), lowest in Victory (10.86), while the figures for Swedish Select (13.69) and Iowar (12.18) are between the two. In this connection it may not be amiss to mention that the acid amide nitrogen, which was obtained by hydrolysis of the purified and concentrated flour extracts for thirty minutes, increased somewhat on prolonged hydrolysis. This may, perhaps, be due to the presence in the oat kernel of compounds other than acid amides, such as purine derivatives. Concerning the peptide nitrogen, whose figures represent the average of from

three to four estimations, it follows the order indicated in the case of the amino acids, being highest in Swedish Select (28.71 per cent.), somewhat lower in Victory (27.16 per cent.), and still lower in Iowar (22.03 per cent.) and Winter Turf (17.88 per cent.), when referred to the water-soluble nitrogen.

The aqueous extracts of the several oat varieties were found to be somewhat acid. Thus, 100 c.c. of the water extracts of Swedish

TABLE III.

Distribution of the Non-protein Nitrogen in the Ungerminated Oat Kernel.

Variety of Oats.	Nitrogen of Amino Acids. Per cent.	Nitrogen of Acid Amides. Per cent.	Peptide Nitrogen. Per cent.
Results Expressed in Percentage of the Water-soluble Nitrogen of the Oat Kernel.			
Swedish Select	17.39	13.69	28.71
Victory	15.08	10.86	27.16
Iowar	14.87	12.18	22.03
Winter Turf	13.79	15.01	17.88
Results Expressed in Percentage of the Total Nitrogen of the Oat Kernel.			
Swedish Select	2.48	1.95	4.10
Victory	2.02	1.45	3.63
Iowar	2.35	1.93	3.49
Winter Turf	1.65	1.80	2.15
Results Expressed in Percentage of the Oven-dried Oat Kernel.			
Swedish Select	0.064	0.051	0.106
Victory	0.040	0.029	0.073
Iowar	0.057	0.046	0.084
Winter Turf	0.025	0.027	0.032

Select, Iowar, and Winter Turf required, respectively, 3.40 c.c., 3.50 c.c. and 4.45 c.c. of $\frac{N}{10}$ NaOH for their neutralization. This slight acidity could hardly have a hydrolyzing effect upon the nitrogen compounds present in the oat kernel considering the comparatively rapid evaporation of the aqueous extracts *in vacuo*. However, in order to obtain certainty in this respect, the amino acid estimation in Iowar and Winter Turf oats was modified so as to strictly *neutralize* their filtered aqueous extracts with $\frac{N}{10}$ NH_3

before their evaporation under diminished pressure took place. It was noticed that in this case the coagulation of the proteins as well as the filtration of the concentrated extracts was accomplished with considerable difficulty. Otherwise the extracts were treated exactly as outlined above, except that prior to their titration with formaldehyde they were distilled with magnesium oxide in a vacuum practically to dryness in order to remove the ammonia. The dry residues were then extracted with hot ammonia-free

TABLE IV.

Distribution of the Non-protein Nitrogen in the Ungerminated Oat Kernel (Hot-water Extraction).

Variety of Oats.	Nitrogen of Amino Acids. Per cent.	Nitrogen of Acid Amides. Per cent.	Peptide Nitrogen. Per cent.
Results Expressed in Percentage of the Water-soluble Nitrogen of the Oat Kernel.			
Victory	15.48	12.03	28.58
Iowar	14.04	13.45	25.69
Results Expressed in Percentage of the Total Nitrogen of the Oat Kernel.			
Victory	2.07	1.61	3.82
Iowar	2.22	2.13	4.07
Results Expressed in Percentage of the Oven-dried Oat Kernel.			
Victory	0.042	0.032	0.077
Iowar	0.053	0.051	0.098

water, concentrated to 100 c.c., of which two portions of 20 c.c. each were oxidized according to the Kjeldahl method, while 50 c.c. of remaining solution were applied to formol titration. This modified mode of work yielded 14.02 per cent. and 14.20 per cent. of amino nitrogen for the Iowar and Winter Turf kernels, respectively, as compared with 14.87 per cent. and 13.79 per cent. obtained by the above method. (Table III.)

The water extracts of the flours of the several oat varieties thus far reported were obtained at room temperature. While the extractions and evaporations *in vacuo* were effected comparatively rapidly, the idea that proteolysis could have taken place under the influence of proteolytic enzymes normally present in the oat kernel.

appeared to be not altogether out of the question. If such were the case it would be hard, if possible at all, to tell how much of the amino acids and polypeptides reported in Table III were *preformed* in the kernels under consideration. It seemed, therefore, imperative to conduct the experiments under conditions by which the enzymes would be completely destroyed prior to the extrac-

TABLE V.

Nitrogen Distribution in the Ungerminated Oat Kernel.

Variety of Oats.	Total Nitrogen. Per cent.	Protein Nitrogen. Per cent.	Non-protein Nitrogen. Per cent.	Nitrogen in Phosphotungstic Precipitate. Per cent.	Nitrogen of Amino Acids. Per cent.	Nitrogen of Acid Amides. Per cent.	Peptide Nitrogen. Per cent.
Results Expressed in Percentage of the Total Nitrogen of the Oat Kernel.							
Swedish Select	100.00	88.65	11.35	6.40	2.48	1.95	4.10
Victory	100.00	90.21	9.79	5.48	2.02	1.45	3.63
Iowar	100.00	90.52	9.48	.....	2.35	1.93	3.49
Winter Turf	100.00	91.03	8.97	5.21	1.65	1.80	2.15
Results Expressed in Percentage of the Oven-dried Oat Kernel.							
Swedish Select	2.59	2.30	0.29	0.165	0.064	0.051	0.106
Victory	2.02	1.82	0.20	0.111	0.040	0.029	0.073
Iowar	2.40	2.17	0.23	.....	0.057	0.046	0.084
Winter Turf	1.50	1.36	0.14	0.078	0.025	0.027	0.032

tions. Accordingly, the work was modified so as to treat the flour samples with boiling hot water which was followed by digestion on the steam bath for from fifteen to thirty minutes. The extracts thus obtained were separated by centrifugation from the solid residues which were again extracted once or twice. Unlike the cold-water extracts which are free from starch, the hot-water extracts are very rich in starch, which it is well to remove as much as possible. Otherwise the further treatment of the extracts is practically identical with that in the above method, so that

the description of the details may be omitted here. The results secured by this method are presented in Table IV.

When we compare the nitrogen percentages of amino acids, acid amides, and polypeptides for Victory and Iowar * in Table IV with those in Table III, we can readily see that while the figures under consideration differ from each other to a certain degree, the differences are not large enough to modify the results obtained by the first method (cold-water extraction). Indeed, the results obtained by the hot-water extraction not only fully corroborate the data presented in Table III, but they show conclusively that amino acids and polypeptides have not been formed during extraction but are *preformed* in the oat kernel.

For the sake of greater convenience and clearness the data recorded in Tables I and III, as well as the results obtained with the phosphotungstic acid precipitate, are summarized in Table V. The data in Table V need some explanation. The protein nitrogen was estimated according to Stutzer's [7] method, which ordinarily yields somewhat too high results and, consequently, too low results for non-protein nitrogen. The latter was calculated by difference from 100. The phosphotungstic acid precipitate contains, in addition to a small quantity of protein which may have escaped precipitation by heat and alcohol, also the nitrogen of proteose, peptone, diamino acids and of bases such as trigonellin. The other nitrogenous compounds have previously been discussed and need no further explanation.

SUMMARY.

(1) It has been shown in this paper that the ungerminated oat kernel contains amino acids and polypeptides.

(2) The proportions of amino acid nitrogen in the varieties Swedish Select, Victory, Iowar, and Winter Turf are, respectively, 2.48, 2.02, 2.35, and 1.65 per cent. calculated on the basis of the total nitrogen, and 0.064, 0.040, 0.057, and 0.025 per cent. on the basis of the oven-dried kernel.

(3) The nitrogen of acid amides in the varieties Swedish Select, Victory, Iowar, and Winter Turf makes up, respectively,

* Swedish Select could not be checked by the hot-water extraction method for want of material, while Winter Turf being chaffy was not considered to be a typical sample.

1.95, 1.45, 1.93, and 1.80 per cent. calculated to the total nitrogen, and 0.051, 0.029, 0.046, and 0.027 per cent. calculated to the oven-dried kernel.

(4) The peptide nitrogen in the varieties Swedish Select, Victory, Iowar, and Winter Turf constitutes, respectively, 4.10, 3.63, 3.49, and 2.15 per cent. calculated on the total nitrogen, and 0.106, 0.073, 0.084 and 0.032 per cent. calculated on the oven-dried kernel.

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Experiments on the Durations of Impacts, Mainly of Bars with Rounded Ends, in Elucidation of the Elastic Theory. J. E. P. WAGSTAFF. (*Proc. Roy. Soc.*, A 733.)—Two bars of metal having the same dimensions were hung by two suspensions of thread for each so that they just touched, when all the suspensions were vertical. One bar was pulled to one side through a measured

distance in a vertical plane passing through the axes of the undisturbed bars. It was released, swung back, struck the bar at rest and for a brief time remained in contact with it. During that time a condenser sent a current of electricity through the surface of contact. This caused a deflection in a ballistic galvanometer. The time the bars remain in contact can be calculated from the deflection of the galvanometer. In all cases the duration of contact was a few ten-thousandths of a second. The faster the impinging bar was moving at the instant of the blow the shorter was the duration of contact. Let us compare the durations for four steel rods of lengths 10.5, 21.3, 40.8 and 61.25 cm., respectively. With a velocity at contact of 10.352 cm./sec. the durations were 1.455, 2.031, 2.940, 3.629 ten-thousandths seconds. When the contact velocities were four times as large the corresponding durations were 1.045, 1.537, 2.289 and 2.943. A study of a series of similar data shows that for long rods the velocity at impact is without effect on the duration, while for short bars the duration varies inversely as about the fourth root of the velocity. The interpretation of the former case is that the duration is just the time it takes a wave of compression, started by the blow, to run to the distant end of the bar and back. For long bars the impact seems to agree with St. Venant's theory, but in short bars it falls in with the statical theory of Hertz. G. F. S.

The Fibrous Structure of Electrolytic Deposits of Metals. R. GLOCKER and E. KAUPP. (*Zeit. f. Phys.*, Vol. 24, No. 2.)—When a sheet of electrolytic copper was traversed by X-rays the diffraction pattern indicated the existence of a fibrous structure in the metal, the axis of the fibres being the direction of the stream lines of the depositing current. It is further claimed that direct proof is furnished of a definite arrangement of the component small crystals in electrolytically deposited metals. When copper is deposited on a copper cathode, the crystals of the metal grow out from the cathode with the perpendicular to the (011) face in the direction of the stream line. The direction of the fibres is always the direction of the greatest speed of crystal growth for the particular crystal concerned and the particular solution used. Nickel, silver, chromium, and iron are like copper in the features investigated. G. F. S.

The Chemical Nature of Purple of Cassius. A. HUBER. (*Physik. Z.*, Jan. 15, 1924.)—The purple of Cassius has been held to be a union of oxides of gold and of tin according to the formula $Au_2O_2.2Sn_2O_2.xH_2O$. Another view, advocated especially by Zsigmondy, is that the gold is not chemically combined but that it is very finely divided in the metallic state. To decide the question, X-ray photographs of the purple were taken by the method of Debye and Scherrer. From a study of the interference lines thus obtained, it is concluded that crystals both of gold and of Sn_2 are present, and that both of these are in colloidal form. G. F. S.

A CONSTANT PRECISION MANOMETER.*

BY

A. F. ZAHM.

Bureau of Construction and Repair, U.S.N., Associate Editor.

For the measurement of fluid pressure, in physical laboratories, it is convenient to have a liquid manometer whose indications at all magnitudes can be read with uniform precision. The manometer tube may be straight and adjustable to steeper angles as the pressure rises, or it may be immovable and of suitably increasing slope toward its upper end. An instrument of the latter type, devised by the writer in 1919, was constructed at the Washington Navy Yard in 1923, for tests of the Bureau of Aeronautics, for use in the Aerodynamical Laboratory, where also a manometer of the first type is in service. The scale drawings for the present instrument were made by Mr. L. H. Crook, who also supervised its construction.

The shape of the tube is determined by the requirement that the displacement ds of the meniscus along the bore must bear a constant ratio to the fractional change dy/y of its head y. The curve of the tube therefore has the form

$$ds/dy = a/y, \tag{1}$$

which is the equation of the tractrix. As seen in Fig. 1, the constant a is the length of the tangent from any point of the curve to the horizontal axis; hence also it is the full height of the complete curve, which is vertical where $y = a$. For $y = 0$ the curve is asymptotic to the horizontal axis, and too distant to be used in a manometer.

For convenience in plotting, the solution of (1) may be taken in its parametric form [1]

$$x = a\,(t - \tanh t);\ y = a/\cosh t \tag{2}$$

where a is the given height of the curve, and t is an auxiliary variable. On substituting for t a series of numerical values, a sufficient number of coördinate values of x and y to plot a curve can quickly be computed by using a table of hyperbolic cosines and tangents.

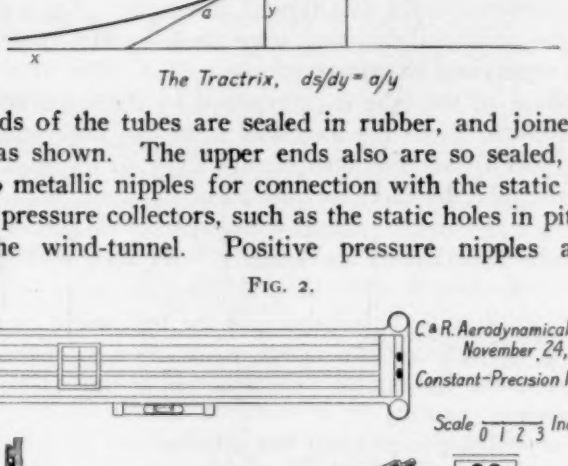
Figs. 2, 3 and 4 disclose the chief features of a constant-precision manometer having two tubes, each with its own alcohol

* Communicated by the Author.

[1] Mark's "Mech. Eng. Handbook," or a textbook on higher plane curves.

cistern. The bulk of the instrument consists of a single aluminum casting having two cisterns cored from its under side, which are milled true and closed with a bottom lid. The top side, which is scraped to the tractrix outline, holds the two glass tubes firmly clamped with metal gibs. As actually shown, a thick rubber strip presses the tubes laterally against their fixed metal gibs. The

FIG. 1.



The Tractrix, ds/dy = a/y

lower ends of the tubes are sealed in rubber, and joined to the cisterns as shown. The upper ends also are so sealed, and are joined to metallic nipples for connection with the static leads of negative pressure collectors, such as the static holes in pitot tubes inside the wind-tunnel. Positive pressure nipples are seen

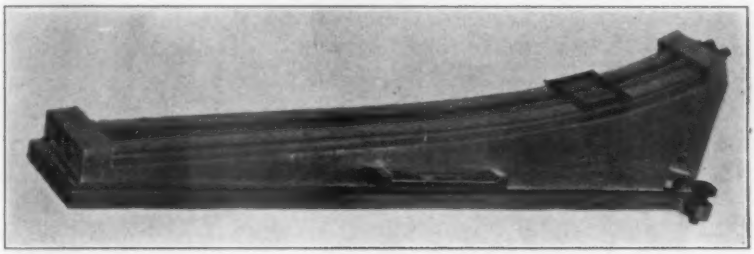
FIG. 2.

threaded into the end of the casting well above the level of the liquid in the cisterns. Below each is a little knurled screw that regulates an immersion float, so as to adjust the level of the alcohol, and thus the zero position of the meniscus in the manometer tube. A fixed spirit level indicates when the instrument has been properly set with the levelling screws shown at its bottom

corners. The exact position of the meniscus along the bore is located either with a ruled piece of celluloid sliding along the gibs as shown or by marks on the glass tube. The detailed dimensions of the instrument can be inferred from the scale in Fig. 2.

Experience had proved that an alcohol meniscus can be nicely located in a glass tube of one-quarter inch bore rising one inch in a length of ten. Furthermore the rise must be 3.4 inches to balance the impact of standard air at seventy-five miles an hour, the usual top speed in the tunnel now using the manometer. Hence the upper part of the tractrix must be about four inches above the surface of the reservoir alcohol, to provide a liberal margin

FIG. 3.



A constant precision manometer, face view.

for the sliding index; while the lower part should have a 1 to 10 slope. The tubes were formed over a fish-tail flame, then annealed by slow cooling in asbestos.

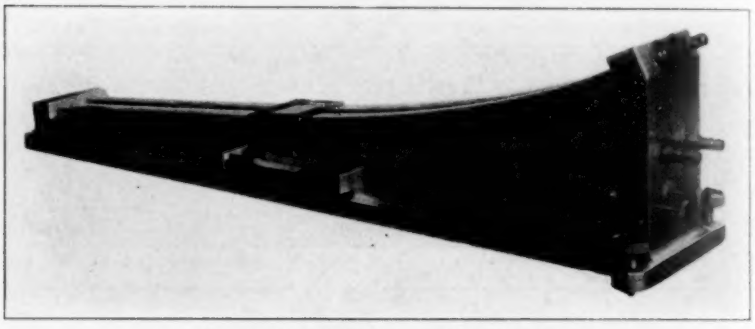
To adjust the manometer, one first levels it and turns the float screws to bring each meniscus to the zero line drawn squarely across the gibs, which are flush with the top of the glass.

For static graduation, successive pressures, as indicated by a hook gauge, are applied to the air in a cistern. The successive altitudes of the liquid column are marked as pressures or inches of water, thus completing the usual static scale.

To graduate a scale to indicate the speed of standard air passing along a pitot-static nozzle whose two leads are joined to a single manometer tube of the instrument, one marks along the bore the heights of the meniscus, above zero level, corresponding to the full-impact pressure for various integral air-speeds, as found in a table of speed *versus* impact pressure. The scale then indicates speeds for standard air at the part of the tunnel where the pitot is fixed.

Sometimes a reference pitot fixed in a convenient part of a wind-tunnel must be made to measure the speed of standard air flowing through the working part of the tunnel, that is the part where the model is to be held for test. Prior to inserting the model one explores its part of the tunnel with a temporary pitot-static tube, connected with one manometer tube, whose readings are thus compared with those of the said fixed pitot connected to the other manometer tube. By working the rheostat that controls the tunnel fan, the readings of the fixed pitot are held constant while the mean readings of the exploring pitot are obtained. The

FIG. 4.



A constant precision manometer, end view.

latter mean readings are plotted against the readings of the fixed reference nozzle. From the resulting plot one chooses pressure-heads for the fixed pitot that shall indicate even miles an hour mean speed where the model is to be tested. These pressure-heads are then marked as miles an hour on or beside the glass tube whose leads run to the fixed pitot. Clear fine marks on the manometer tube, enabling one to locate the meniscus easily without the sliding index, are preferred in practice.

One use of the manometer is to enable a wind-tunnel observer to set the air-speed at a definite figure, by suitably adjusting the rheostat or other control; then to observe the minor oscillations or the slow and gradual change of speed. In many tunnels these changes are manually compensated; in others they are automatically obviated or compensated. When the control is automatic the manometer may still be used as an air-speed indicator to assure the observer that the automatic control is functioning with ample precision.

A PROBLEM IN TRANSIENT PHENOMENA IN COUPLED CIRCUITS.*

BY

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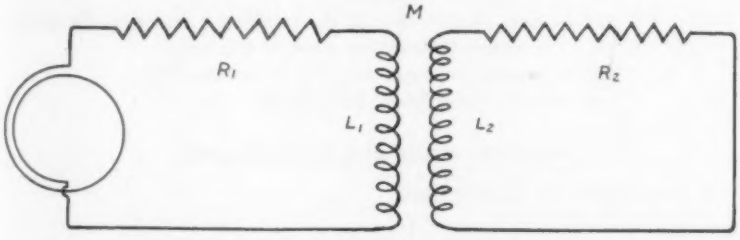
PART I.

THERE is a device in common use for measuring the velocity of magnetized projectiles which records the instant of passage of the projectile through a circular coil by means of a chronographic record of the currents induced in a circuit in series with or magnetically coupled with that coil. Since these circuits contain inductance, the currents will not in general be in phase with the electromotive force, which means that there will be a small time error in the determination of the instant of passage from the

FIG. 1.



current curves. For accurate work it is desirable to know these time differences, which we shall designate time lags.

Since the fundamental differential equations for coupled circuits are well known, this problem can be solved mathematically. It is a simple matter to obtain expressions for the currents in terms of a single type of integral, but the evaluation of the integral offers difficulties. The present paper deals with the evaluation of this integral and with the approximations for special cases which will show the general trend of the phenomena as certain parameters vary.

* Communicated by Dr. C. B. Bazzoni. Contribution from the Randal Morgan Laboratory of Physics.

The problem may be formulated as follows: Two electrical circuits containing only resistance and inductance are magnetically coupled by an air-core transformer. In the primary is a circular coil. An ideal bar magnet, whose axis coincides with the axis of the coil, moves along this axis with a uniform velocity, V, thus generating a momentary electromotive force. The problem is to determine the variation with time of the electromotive force and the currents in the primary and secondary: A diagram of the circuits is given in Fig. 1.

Notation:

E = e.m.f. induced in the circular coil;
i_1 = current in primary;
i_2 = current in secondary;
R_1 = resistance of primary;
R_2 = resistance of secondary;
L_1 = self-inductance of primary;
L_2 = self-inductance of secondary;
M = mutual inductance;
$2a$ = length of bar magnet;
b = radius of circular coil;
V = velocity of magnet;
t = time, measured from the instant the centre of the magnet passes through the plane of the coil;
N = number of turns of wire in circular coil;
m = pole strength of the magnet.

THE E.M.F. CURVE AND THE CURRENTS.

It can easily be shown that

$$E = f(t) = p\left\{\frac{1}{[(Vt-a)^2+b^2]^{\frac{3}{2}}} - \frac{1}{[(Vt+a)^2+b^2]^{\frac{3}{2}}}\right\}, \tag{1}$$

where, if E is to be in volts,

$$p = \frac{2\pi N b^2 V m}{10^8} \tag{2}$$

when c. g. s. units are used.

Let

$$\left.\begin{aligned} c &= \frac{a}{b} \\ u &= \frac{Vt}{b} \end{aligned}\right\}. \tag{3}$$

Then

$$E = \frac{p}{b^3}\varphi(u) = \frac{p}{b^3}\left\{\frac{1}{U_1^3} - \frac{1}{U_2^3}\right\}, \tag{4}$$

where

$$\left.\begin{aligned} U_1 &= \sqrt{(u-c)^2+1} \\ U_2 &= \sqrt{(u+c)^2+1} \end{aligned}\right\}. \tag{5}$$

The general shape of the e.m.f. curve is the same as that of the i_1, u curve in Fig. 2 (c), which was plotted for $c = 1.174$, the value based on the apparatus used in the experimental tests.

The differential equations for the currents are the well-known equations for coupled circuits:

$$L_1 \frac{di_1}{dt} + M \frac{di_2}{dt} + i_1 R_1 = f(t) = E, \tag{6}$$

$$L_2 \frac{di_2}{dt} + M \frac{di_1}{dt} + i_2 R_2 = 0. \tag{7}$$

Introducing the condition

$$i_1 = i_2 = 0 \text{ when } t = \pm \infty,$$

the solutions of (6) and (7) are

$$i_1 = \frac{\sigma}{\alpha_0 - \beta_0} \left\{ (\alpha_0 L_2 - R_2) e^{-\alpha_0 t} \int_{-\infty}^{t} e^{\alpha_0 \tau} f(\tau)\, d\tau - (\beta_0 L_2 - R_2) e^{-\beta_0 t} \int_{-\infty}^{t} e^{\beta_0 \tau} f(\tau)\, d\tau \right\}, \tag{8}$$

$$i_2 = \frac{\sigma M}{\alpha_0 - \beta_0} \left\{ \beta_0 e^{-\beta_0 t} \int_{-\infty}^{t} e^{\beta_0 \tau} f(\tau)\, d\tau - \alpha_0 e^{-\alpha_0 t} \int_{-\infty}^{t} e^{\alpha_0 \tau} f(\tau)\, d\tau \right\}. \tag{9}$$

Where

$$\sigma = \frac{1}{L_1 L_2 - M^2}, \tag{10}$$

$$k = \frac{M}{\sqrt{L_1 L_2}}, \tag{11}$$

$$\alpha_0, \beta_0 = \frac{1}{2(1-k^2)} \left\{ \frac{R_1}{L_1} + \frac{R_2}{L_2} \pm \sqrt{\left(\frac{R_1}{L_1} - \frac{R_2}{L_2} \right)^2 + 4k^2 \frac{R_1}{L_1} \cdot \frac{R_2}{L_2}} \right\}. \tag{12}$$

Equation (12) shows that α_0 and β_0 are always positive. Take $\alpha_0 \geq \beta_0$.

Let

$$\left.\begin{aligned} \frac{R_1}{L_1}\frac{b}{V} &= \alpha_1 \\ \frac{R_2}{L_2}\frac{b}{V} &= \alpha_2 \\ \frac{\alpha_0 b}{V} &= \alpha \\ \frac{\beta_0 b}{V} &= \beta \end{aligned}\right\}. \tag{13}$$

By means of transformations (3) and (13), equations (8), (9) and (12) can be put into the following form:

$$\alpha, \beta = \frac{1}{2(1-k^2)} \left\{ \alpha_1 + \alpha_2 \pm \sqrt{(\alpha_1 - \alpha_2)^2 + 4k^2\alpha_1\alpha_2} \right\}, \tag{14}$$

$$i_1 = \frac{k_1}{\alpha - \beta} \Big\{ (\alpha - \alpha_2)\,[I(\alpha, u-c) - I(\alpha, u+c)] - (\beta - \alpha_2)\,[I(\beta, u-c) - I(\beta, u+c)] \Big\}. \tag{15}$$

$$i_2 = \frac{k_2}{\alpha - \beta} \Big\{ \beta\,[I(\beta, u-c) - I(\beta, u+c)] - \alpha\,[I(\alpha, u-c) - I(\alpha, u+c)] \Big\}. \tag{16}$$

Where

$$I(\lambda, u) = e^{-\lambda u} \int_{-\infty}^{u} e^{\lambda y} \frac{dy}{(y^2+1)^{\frac{1}{2}}}, \tag{17}$$

$$k_1 = \frac{q}{L_1(1-k^2)}, \tag{18}$$

$$k_2 = \frac{qk}{\sqrt{L_1 L_2}\,(1-k^2)}, \tag{19}$$

and

$$q = \frac{2\pi Nm}{10^8}. \tag{20}$$

We see from (15) and (16) the shape of the i, u curves is a function of the parameters α_1, α_2, k, and c, since α and β are functions of α_1, α_2, and k.

The problem is thus reduced to the evaluation of a one-parameter integral.

METHODS OF INTEGRATION.

The chief difficulty in this problem is evaluating the integral (17). We give five methods adapted to different values of λ.

The First Method: For large values of λ the best integral formula for evaluating (17) is the following one obtained by successive partial integration:

$$e^{-\lambda u} \int_{-\infty}^{u} e^{\lambda y} \frac{dy}{(y^2+1)^{\frac{1}{2}}} = \frac{1}{\lambda} \cdot \frac{1}{(u^2+1)^{\frac{1}{2}}} + \frac{1}{\lambda^2} \cdot \frac{3u}{(u^2+1)^{\frac{1}{2}}} + \frac{1}{\lambda^3} \cdot \frac{3(4u^2-1)}{(u^2+1)^{\frac{1}{2}}} + \frac{1}{\lambda^4} \cdot \frac{15u(4u^2-3)}{(u^2+1)^{\frac{1}{2}}} + \frac{1}{\lambda^4} e^{-\lambda u} \int_{-\infty}^{u} e^{\lambda y} \frac{45(1-12y^2+8y^4)\,dy}{(y^2+1)^{\frac{1}{2}}} \tag{21}$$

The ratio, R, of the integrand of the integral on the right, to that of the integral on the left, is

$$R = \frac{45\,(1 - 12y^2 + 8y^4)}{\lambda^4\,(y^2 + 1)^4}.$$

The maximum numerical value of R is $R = \frac{45}{\lambda^4}$. Hence if λ is large enough, the last integral is negligible. If $\lambda > 8.2$ the integrand of the last integral is everywhere less than 1 per cent. of the integrand of the original integral. It can also be shown that for

$$|y| > 1.704\,,\ R < \frac{6.74}{\lambda^4};$$

so that for

$$\lambda > 5.1\,,\ u < -1.704$$

the integrand of the last integral is everywhere less than 1 per cent. of the integrand of the original integral.

The Second Method: The second, third, and fourth methods, though valid for all values of λ and u, do not lend themselves to numerical computation with equal facility in all cases. The second method is best adapted to values of λ just too small to use the first method.

By a combination of partial integration and expansion in series,

$$\begin{aligned} e^{-\lambda u}\int_{-\infty}^{u} e^{\lambda y}\frac{dy}{(y^2+1)^{\frac{1}{2}}} &= \frac{1}{\lambda}\cdot\frac{1}{(u^2+1)^{\frac{1}{2}}} \\ &+ \frac{3}{\lambda}\,e^{-\lambda u}\Big\{\sum_{M=0}^{\infty} c_M u^M\,(u^2+1)^{-\frac{1}{2}} \\ &+ c_{-1}\log\left(\sqrt{u^2+1}+u\right) + g_1(\lambda)\Big\}, \end{aligned} \tag{22}$$

Where

$$c_M = \frac{\lambda^M}{M!}\cdot\frac{1}{(M-3)}\sum_{s=0}^{\infty}\frac{(-1)^s\,(M-1)\,(M+2s-1)\,\lambda^{2s}}{[(M-1)\,(M+1)\cdots(M+2s-1)]^2} \tag{23}$$

for $M = 0, 2, M \geq 4$,

$$c_3 = \frac{\lambda}{3} - \frac{4}{3}\,\frac{\lambda^3}{3!}\sum_{s=0}^{\infty}\frac{(-1)^s\,2(2s+2)\,\lambda^{2s}}{[2\cdot 4\cdot 6\cdots(2s+2)]^2}, \tag{24}$$

$$c_1 = -\frac{\lambda^3}{3!}\sum_{s=0}^{\infty}\frac{(-1)^s\,2\,(2s+2)\,\lambda^{2s}}{[2\cdot 4\cdot 6\cdots(2s+2)]^2}, \tag{25}$$

$$c_{-1} = -c_1;$$

and $g_1(\lambda)$ is a constant.

It can be determined by comparing the value of

$$\int_{-\infty}^{0} e^{\lambda y}\frac{dy}{(y^2+1)^{\frac{1}{2}}}$$

obtained from (22) with that obtained from the formula

$$\int_{-\infty}^{0} e^{\alpha y} (y^2 + c^2)^{-\frac{1}{2}} \, dy = \frac{\alpha}{c} \left[K_1 (\alpha c) - \frac{\pi}{2} Z_0' (\alpha c) \right]. \tag{26}$$

Where

$$Z_0' (x) = \frac{2}{\pi} \sum_{s=0}^{\infty} \frac{(-1)^s x^{2s}}{[1 \cdot 3 \cdot 5 \cdots (2s-1)]^2 (2s+1)} \tag{27}$$

$$K_1 (x) = -\frac{\pi}{2} N_1 (x),$$

And $N_1 (x)$ is Neumann's cylindrical harmonic of the first order.[1]

The formula for $g_1 (\lambda)$ is

$$g_1 (\lambda) = \frac{\lambda^2}{3} \left[K_1 (\lambda) - \frac{\pi}{2} Z_0' (\lambda) \right] - \frac{1}{3} - c_0. \tag{28}$$

The third method is best adapted to intermediate values of λ in the neighborhood of $\lambda = 1$.

By expansion into series we obtain

$$\int_{-\infty}^{u} e^{\lambda y} \frac{dy}{(y^2+1)^{\frac{1}{2}}} = \sum_{M=0}^{\infty} d_M u^M (u^2+1)^{-\frac{1}{2}} + d_{-1} \log \left(\sqrt{u^2+1} + u \right) + g_2 (\lambda). \tag{29}$$

Where

$$d_M = \frac{\lambda^{M+1}}{(M+1)!} \cdot \frac{1}{(M-1)} \sum_{s=0}^{\infty} \frac{(-1)^s (M+1)(M+2s+1) \lambda^{2s}}{[(M+1)(M+3) \cdots (M+2s+1)]^2} \tag{30}$$

for $M = 0$, $M \geq 2$,

$$d_{-1} = \frac{\lambda^2}{2} \sum_{s=0}^{\infty} \frac{(-1)^s (2s+2) \lambda^{2s}}{[2 \cdot 4 \cdot 6 \cdots (2s+2)]^2}, \tag{31}$$

$$d_1 = 1 - d_{-1}; \tag{32}$$

also

$$d_{M+2} = \frac{\lambda^{M+1}}{(M+2)!} - \frac{(M-1)}{(M+2)} d_M \tag{33}$$

for $M \geq 2$.

The constant of $g_2 (\lambda)$ can be determined in the same manner as $g_1 (\lambda)$ and is

$$g_2 (\lambda) = \lambda \left[K_1 (\lambda) - \frac{\pi}{2} Z_0' (\lambda) \right] - d_0. \tag{34}$$

[1] The notation here is that of the Jahnke-Emde "Funktionentafeln," p. 93, where $K_1(x)$ and $N_1(x)$ are defined and tabulated. Formula (26) is easily derived by differentiation from equation (2) in Nielsen's "Handbuch der Theorie der Cylinderfunktionen," p. 224, for the case $v = 0$.

The Fourth Method: This is convenient for small values of λ.

By a combination of partial integration and expansion into series

$$e^{-\lambda u}\int_{-\infty}^{u} e^{\lambda y}\frac{dy}{(y^2+1)^{\frac{1}{2}}} = \frac{u}{\sqrt{u^2+1}}$$

$$-\lambda e^{-\lambda u}\left\{\sum_{M=0}^{\infty} f_M u^M\sqrt{u^2+1}+f_{-1}\log\left(\sqrt{u^2+1}+u\right)-g_3(\lambda)\right\}, \quad (35)$$

where

$$f_M = \frac{\lambda^M}{M!}\sum_{s=0}^{\infty}\frac{(-1)^s(M+2s+1)\lambda^{2s}}{[(M+1)(M+3)\cdots(M+2s+1)]^2} \quad (36)$$

for $M \geq 0$.

$$f_{-1} = -f_1;$$

Also

$$f_{M+2} = \frac{1}{M+2}\left\{\frac{\lambda^M}{M!}-(M+1)f_M\right\}. \quad (37)$$

Equation (35) can be put into the form

$$e^{-\lambda u}\int_{-\infty}^{u} e^{\lambda y}\frac{dy}{(y^2+1)^{\frac{1}{2}}} = \frac{u}{\sqrt{u^2+1}}-(1-e^{-\lambda u})\frac{\sqrt{u^2+1}}{u}$$

$$-\lambda e^{-\lambda u}\left\{\sum_{M=0}^{\infty} k_M u^M\sqrt{u^2+1}+f_{-1}\log\left(\sqrt{u^2+1}+u\right)-g_3(\lambda)\right\}, \quad (38)$$

where

$$k_M = \frac{\lambda^M}{M!}\sum_{s=1}^{\infty}\frac{(-1)^s(M+2s+1)\lambda^{2s}}{[(M+1)(M+3)\cdots(M+2s+1)]^2} \quad (39)$$

and

$$g_3(\lambda) = \left[K_1(\lambda)-\frac{\pi}{2}Z_o'(\lambda)\right]+f_o$$

All the series in the last three methods coverge for all values of λ and u.

The Fifth Method: For values of $\lambda > 1$ and too small to use the first method, the next three methods are not very satisfactory for the larger negative values of u. The following formula is better in this case.

Expanding the binomial factor,

$$e^{-\lambda u}\int_{-\infty}^{u} e^{\lambda y}\frac{dy}{(y^2+1)^{\frac{1}{2}}} = \sum_{M=0}^{\infty} a_M u^{-M}+a_{-1}e^{-\lambda u}Ei(\lambda u) \quad (40)$$

for $u < -1$,

Where [2]

$$a_M = -\sum_{s=1}^{\infty} \frac{(M-1)!\, l_{M+s}\lambda^{s-1}}{(M+s-1)!} \tag{41}$$

for $M \geq 1$,

$$a_0 = 0$$

$$a_{-1} = -\lambda a_1$$

And

$$l_M = 0$$

for M even;

$$l_M = \frac{(-1)^{\frac{M-1}{2}}(M-2)!}{2^{M-3}\left[\left(\frac{M-3}{2}\right)!\right]^2}$$

for M odd.

APPROXIMATIONS AND INTERPRETATION OF RESULTS.

(a) It can easily be shown that in the case when α and β are infinitesimal, (15) and (16) reduce to

$$i_1 = k_1\left\{\frac{u-c}{U_1} - \frac{u+c}{U_2}\right\}, \tag{42}$$

$$i_2 = -k_2\left\{\frac{u-c}{U_1} - \frac{u+c}{U_2}\right\}. \tag{43}$$

The shape of these curves is shown in Fig. 2 (a), which was plotted for $c = 1.174$.

(b) A second approximation.

Everything of importance happens in an interval $|u| < 10$ unless $c > 2$ or 3.

Therefore, if $\alpha, \beta < .01$,

$$e^{\alpha u} = 1 + \alpha u$$

$$e^{\beta u} = 1 + \beta u$$

for $|u| < 10$ to within less than 1 per cent. It can be shown that under these conditions equations (15) and (16) reduce to

$$i_1 = k_1\left\{\frac{u-c}{U_1} - \frac{u+c}{U_2} - (\alpha+\beta-\alpha_2)(U_1 - U_2 - 2c)\right\}, \tag{44}$$

$$i_2 = -k_2\left\{\frac{u-c}{U_1} - \frac{u+c}{U_2} - (\alpha+\beta)(U_1 - U_2 - 2c)\right\}. \tag{45}$$

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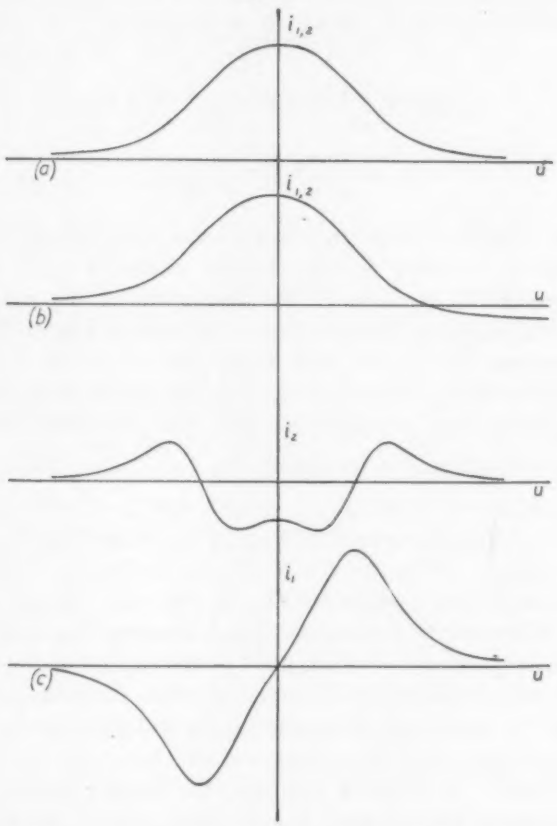
[2] $$Ei(x) = \int_{\infty}^{-x} \frac{e^{-x}dx}{x} = \int_{-\infty}^{x} \frac{e^x dx}{x}.$$

It is defined and tabulated in the Jahnke-Emde "Funktionentafeln," pp. 19–23.

Since both $(\alpha+\beta)$ and $(\alpha+\beta-\alpha_2)$ are positive, the i_1, u curve and the i_2, u curve have the same general shape, which is illustrated in Fig. 2 (b), which was plotted for $c = 1.174$.

FIG. 2.



(c) An approximation for large values of α and β.

By partial integration

$$e^{-\lambda u}\int_{-\infty}^{u} e^{\lambda y}\frac{dy}{(y^2+1)^{\frac{1}{2}}} = \frac{1}{\lambda}\frac{1}{(u^2+1)^{\frac{1}{2}}} + \frac{1}{\lambda^2}\cdot\frac{3u}{(u^2+1)^{\frac{1}{2}}} \tag{46}$$

$$+\frac{3}{\lambda^2}\,e^{-\lambda u}\int_{-\infty}^{u} e^{\lambda y}\frac{(4y^2-1)}{(y^2+1)^{\frac{1}{2}}}\,dy.$$

The ratio, R_1, of the integrand of the last integral to that of the original integral is $R_1 = \frac{3}{\lambda^2}\frac{4y^2-1}{(y^2+1)^2}$

The maximum numerical value of R_1 is $R_1 = \frac{3}{\lambda^2}$. Hence if R_1 is to be less than 1 per cent., $\lambda > 18$.

Consequently for $\alpha, \beta > 18$

$$i_1 = \frac{k_1}{\alpha\beta}\left\{\alpha_2\left(\frac{1}{U_1^3} - \frac{1}{U_2^3}\right)\right. \tag{47}$$

$$\left. + \frac{3[\alpha_2(\alpha+\beta) - \alpha\beta]}{\alpha\beta}\left[\frac{u-c}{U_1^5} - \frac{u+c}{U_2^5}\right]\right\},$$

$$i_2 = \frac{3k_2}{\alpha\beta}\left\{\frac{u-c}{U_1^5} - \frac{u+c}{U_2^5}\right\}. \tag{48}$$

These equations show that in this case, neglecting a numerical factor, the i_1, u curve is only slightly different from the e.m.f. curve, and the i_2, u curve is the derivative of the e.m.f. curve. The general shape of these curves is shown in Fig. 2 (c), which was computed for α and β infinite and $c = 1.174$. The slight maximum in the i_2, u curve at $u = 0$ is due to the large value of c. As c decreases this becomes less and less prominent, and finally vanishes and becomes a minimum for $c < \frac{1}{2}\sqrt{3} = .866$.

Comparison of Figs. 2 (a), 2 (b), and 2 (c) shows the general trend of the phenomena as α and β increase from small values to large values. When $\alpha = \beta = 0$, the i, u curves for both primary and secondary are similar to Fig. 2 (a) and do not cross the u-axis. When α and β are small the i, u curves for both primary and secondary, shown in Fig. 2 (b), are similar in their general characteristics to the e.m.f. curve in that each has one maximum and one minimum, cross the u-axis and are zero for $u = \pm\infty$. The second numerical maximum is small, however, in comparison with the first. As α and β increase, the second numerical maximum increases with respect to the first, and it would seem as though there must be cases where both i, u curves are very similar indeed to the e.m.f. curve, though displaced along the u-axis. If α and β are increased still further, the i_1, u curve approaches coincidence, neglecting a numerical factor, with the e.m.f. curve, while the i_2, u curve begins crossing the u-axis a second time and approaches coincidence, again neglecting a numerical factor, with the time derivative of the e.m.f. curve. These conclusions are based on a consideration of the approximation cases (a), (b), and (c), and must not be interpreted too rigorously.

(*d*) The case when $\beta = 0$.

If either $\alpha_1 = 0$ or $\alpha_2 = 0$, then from (14) $\beta = 0$, and from (16)

$$i_2 = -k_2 [I(\alpha, u - c) - I(\alpha, u + c)]. \tag{49}$$

If α is small the i_2, u curve has in this case the shape shown in Fig. 2 (*b*). If α is very large, however, it can be shown just as in case (*c*) that

$$i_2 = -\frac{k_2}{\alpha}\left\{\frac{1}{U_1^2} - \frac{1}{U_2^2}\right\} = -\frac{k_2}{\alpha}\varphi(u), \tag{50}$$

which shows that disregarding the numerical factor, the i_2, u curve coincides with the e.m.f. curve.

It follows that when $\beta = 0$, the i_2, u curve cannot cross the axis more than once.

TIME LAGS.

If t_{o_1} and t_{o_2} are values of t such that

$$i_1 = 0 \text{ when } t = t_{o1},$$
$$i_2 = 0 \text{ when } t = t_{o2}$$

we may call t_{o_1} and t_{o_2} the time lags of primary and secondary, respectively. Let u_{o_1} and u_{o_2} be the corresponding values of u. From (3)

$$t = \frac{b}{V}u. \tag{51}$$

From (15) and (16) we saw that the shape of the i, u curves was a function of α_1, α_2, k, and c. Hence u_{o_1} and u_{o_2} are functions only of α_1, α_2, k, and c. It follows then from (13) and (51) that varying the factors in α_1 and α_2 while keeping α_1, α_2, k, and c constant, we can vary the time lags. From (51), if we take $\frac{b}{V}$ small and $\frac{R_1}{L_1}$ and $\frac{R_2}{L_2}$ large, the time lags will be relatively small; while if we take $\frac{b}{V}$ large and $\frac{R_1}{L_1}$ and $\frac{R_2}{L_2}$ small, the time lags will be relatively large. This is what one would expect independently of the mathematics.

PART II.

THE EFFECT OF OBLIQUITY AND ECCENTRICITY OF THE TRAJECTORY ON THE E.M.F. CURVE.

Equations (1) and (4) were derived for the case when the magnet, moving in the direction of its axis, passes perpendicularly through the centre of the coil. It can be shown that if the

magnet moving in the direction of its axis passes perpendicularly through the coil at a distance d from the centre of the coil, the e.m.f. is given to the third order of approximation by the expression,

$$E = \frac{p}{b^3}\left\{\frac{1}{U_1^3}\left[1+\left(\frac{15}{4}\frac{1}{U_1^2}-3\right)\frac{g^2}{U_1^2}\right]\right. \tag{52}$$
$$\left.-\frac{1}{U_2^3}\left[1+\left(\frac{15}{4}\frac{1}{U_2^2}-3\right)\frac{g^2}{U_2^2}\right]\right\},$$

where $g=\frac{d}{b}$. This reduces to (4) for $g=0$ and is only slightly different from (4) if $g<.1$.

It can also be shown that if the magnet moving in the direction of its axis passes through the centre of the coil along a line making an angle θ with the axis of the coil, the e.m.f. to the third order of approximation is

$$E = \frac{p}{b^3}\left\{\frac{1}{U_1^3}\left[1-\frac{1}{4}\sin^2\theta+\frac{15}{4}\frac{(u-c)^2\sin^2\theta}{U_1^4}\right]\right.$$
$$\left.-\frac{1}{U_2^3}\left[1-\frac{1}{4}\sin^2\theta+\frac{15}{4}\frac{(u+c)^2\sin^2\theta}{U_1^4}\right]\right\}. \tag{53}$$

The expressions in brackets differ from unity by less than 1 per cent. if $\sin\theta<.05$.

Finally, it can be shown that if the trajectory of the centre of the magnet passes perpendicularly through the centre of the coil and the magnet is inclined to its trajectory by an angle θ', the e.m.f. to the second order of approximation is

$$E = p\left\{\frac{1}{T_1^3}\left[1+\left(\frac{15}{4}\frac{b^2}{T_1^2}-3\right)\frac{a^2\sin^2\theta'}{T_1^2}\right]\right.$$
$$\left.-\frac{1}{T_2^3}\left[1+\left(\frac{15}{4}\frac{b^2}{T_2^2}-3\right)\frac{a^2\sin^2\theta'}{T_2^2}\right]\right\} \tag{54}$$

Where

$$T_1=\sqrt{(Vt-a\cos\theta')^2+b^2}$$

$$T_2=\sqrt{(Vt+a\cos\theta')^2+b^2}.$$

This shows that the effect of the tilt is small for $\sin\theta'<.1$, if $\frac{a}{b}=c<$ about 1.

The more general case, the one most likely to occur in practice, where the magnet making an angle with its trajectory passes through the coil eccentrically along a line making an angle with the axis of the coil, has been investigated by the author. The

resulting formula for the e.m.f. is of the second order in the deviating quantities, indicating that the errors due to small deviations are negligible.

Experimental tests were carried out and the theory of Part I verified to a satisfactory degree of approximation.

In conclusion the writer wishes to express his indebtedness to Dr. E. A. Eckhardt, of the Bureau of Standards, who proposed this problem, and to Drs. H. C. Richards and C. B. Bazzoni for valuable suggestions received during the investigation.

Changes Produced by Mechanical Stress in the Temperature Coefficient of the Electrical Resistance of Pure Platinum. O. Feussner. (*Zeit. f. Phys.*, Vol. 21, No. 3.)—"All measurements without exception give the result that the purer the metals are the higher is their temperature coefficient, and, likewise, that for the attainment of high values careful mechanical treatment is necessary. According to Credner's investigations a wire shows the highest coefficient after it has been kept at from 500° to 600° for ten minutes or for a correspondingly shorter time at a higher temperature. Treatment for a longer time is followed by a diminution of the coefficient. A decrease in the temperature coefficient due to mechanical stress has been known for a long time, but endeavors to connect the change with the amount of the previous stress have led to very unreliable proposals." The author makes his contribution to the solution of the problem by studying the effect of the stretching of a wire upon its temperature coefficient. Not satisfied merely to assume that under tension a wire is elongated uniformly throughout its entire length rather than that it yields at certain places only, he examines these two possibilities by a comparison of the change of resistance with change of length and concludes that uniform extension does really take place.

A wire of pure platinum, .1 mm. in diameter, was spanned vertically in an oil bath whose temperature could be varied. Its lower end was fixed and it was stretched by an upward pull. Parallel to the first a second comparison wire of platinum of the same quality was stretched, but during the experiment there was no change in its tension. The procedure of measurement was about this. With the bath at zero the resistance of the comparison wire was measured and also that of the experimental wire stretched by a known force. The temperature was then raised to 100° and the two measurements repeated. Owing to the rise of temperature of the metal the resistances at 100° are both roughly 39 per cent. greater than those at zero. The resistance of the comparison wire at 100° was divided by its resistance at 0° and, likewise, the resistance of the stretched wire at 100° was divided by its resistance at 0°. If tension were without effect on the temperature coefficient, these quotients should be the

same. They never are equal, the quotient for the comparison wire in a great majority of the cases being the larger, though generally by only a fraction of 1 per cent. Of course, the experimental wire was measured under different loads. The author concludes that his experiments furnish no support to the belief that tension causes the temperature coefficient to vary. Whatever differences were observed may well be due to errors of experiment. G. F. S.

On the Electric Conductivity and Transformation Points of Glasses. H. SCHÖNBORN. (*Zeit. f. Phys.*, Vol. 22, No. 5.)—"Investigations on the thermal expansion coefficients of glasses at high temperatures have shown that at such temperatures anomalies arise in the coefficients that seem to indicate the occurrence of molecular transformations in the glass. An almost linear expansion takes place up to from 350° to 500° according to the sort of glass. Then, in glass free from internal strain, there comes a critical zone in which the expansion rapidly increases. At still higher temperatures there succeeds another range of linear expansion, wherein the expansion coefficient is two to seven times as great as below the critical zone. Above this softening of the glass occurs." In this paper it is the electrical conductivity of various glasses that forms the subject of examination and, in particular, the relation of this conductivity to the critical zone. In all of the dozen kinds investigated there is detected at least one temperature at which the resistance changes in such a manner as to point toward a transformation in the glass, and in several instances there are two such temperatures. In all cases these temperatures are fairly coincident with one or both of the limits of the critcial zone as marked off by experiments on the thermal expansion of the glass. In some glasses, when the temperature has been raised beyond a transformation point, a reduction of temperature causes the electrical resistance to follow a course as the temperature descends that is not the same as that pursued as the temperature rises. At the same temperature the resistances are smaller with falling than with rising temperature. G. F. S.

Relations between Terrestrial Magnetism and Atmospheric Conditions. A. NODON. (*Comptes Rendus*, April 14, 1924.)—A study of atmospheric conditions and of the magnetic elements at the same time in the southwestern part of France has led to the following conclusions, that an increase in magnetic intensity always occurs when an elevation of temperature first manifesting itself in the higher regions of the atmosphere comes gradually down to the earth, that a decrease in intensity accompanies the downward movement of a lower temperature, and that electromagnetic disturbances such as are characterized by sudden and regularly occurring changes in magnetic intensity and in the electrical charge of the earth are generally followed by atmospheric and seismic perturbations whose focus is located far from the place of observation. G. F. S.

A NEW INSTRUMENT FOR RECORDING LINEAR ACCELERATIONS.*

BY

F. H. NORTON.

Massachusetts Institute of Technology.

ONE usually thinks of a physical instrument as a more or less delicate piece of apparatus reposing quietly on a laboratory table. Now let this table be transformed into a small cupboard—barely large enough to hold a derby hat—crowded into the fusilage of an airplane where severe vibrations, accelerations and extremes of temperature are experienced. What changes must be made in the usual type of instrument to enable it to record accurately under these unfavorable conditions? The problems presented the instrument designer are both difficult and interesting, requiring new methods and new materials as well as a radical departure from the usual instrument practice for their solution. The way in which some of them have been solved in designing an accelerometer is described in the following paper.

The principle used in measuring a linear acceleration is very simple. Newton's second law states that the acceleration of a given mass is proportional to the force acting on it. Or the acceleration can be measured by the force exerted by a given mass. This force can be measured most readily by the deflection of a spring supporting the mass. The accelerometer then consists in its simplest form of a mass supported by a spring, with means for recording the deflection of the latter.

When the acceleration changes rapidly, as is often the case, the natural frequency of the mass and spring must be selected with care. For should the frequency of the spring be much lower than that of the acceleration, the deflection of the mass would be a measure of displacement as in the siesmograph. If the two frequencies are of the same order a combination of acceleration and displacement will be measured and at resonance the deflections will be far greater than under any other condition. To accurately measure acceleration the frequency of the spring must be three to

* Communicated by Dr. Joseph S. Ames, Associate Editor of this JOURNAL.

five times that of the acceleration. For airplane and automobile work it has been found desirable to use a spring and mass with a natural frequency of 50 to 100 vibrations per second. To secure accurate readings it is also quite necessary to have the proper damping of the spring.[1]

In laying out a new instrument it is desirable to set down the general requirements and then to try to fulfil them as far as possible. In this accelerometer the following features were desired to the fullest possible extent in the order of their importance:

(1) Small bulk and weight, including batteries.
(2) An accuracy of at least 0.1 g. in measuring accelerations with frequencies up to 20 per cent.
(3) The operation to be unaffected by vibration, accelerations or temperature.
(4) Ease of adjustment and accessibility.
(5) Ruggedness and dependability.

The factors determining the size of the instrument are primarily the width and length of film, the length of the accelerometer spring and the size of the driving motor.

The width of the film should be sufficient not only to give the desired precision but it should also allow a direct visual examination without eye strain. It may be safely assumed that the record on the film can be read to the nearest 0.01 inch,[2] which for a 10-g. range (1 g. = 0.1 inch) gives a one-inch width. A record of this size can be seen readily and yet is quite compact. The nearest commercial film to this size is moving picture film, 1⅜ inches wide, and this was selected for use in the instrument. The length of the film should be enough to take all the records necessary on one trip. For all occasions, one-half hour was considered sufficient, which gives a length of eighteen feet for the satisfactory rate of seven inches per minute. When this film is wound on the smallest practicable spool the outside diameter is about $1^{3}/_{16}$ inches.

It is necessary to measure as nearly as possible only one component of acceleration at a time. Therefore, a flat cantilever spring as first suggested by Prof. E. P. Warner for the N.A.C.A.

[1] "Accelerometer Design," F. H. Norton and E. P. Warner, Nat. Advisory Comm. for Aeronautics, Report No. 100.

[2] "Photographic Recording of Small Motions," F. H. Norton, Nat. Advisory Comm. for Aeronautics, T. N. No. 22.

accelerometer is found most suited for this instrument. The minimum length of the spring is determined only by the inertia and friction of the recording device (for the spring must be large enough to be uninfluenced in its motion by the latter). Experience has shown that where the record is made with a rocking mirror, a free spring length of three to four inches is satisfactory.

Probably the smallest direct current, governed motor giving satisfactory service is 2.5 inches in diameter, 4.2 inches long and weighs 1.8 pounds. A clock capable of running one-half hour at the desired speed would be fully as large. But this is almost as large as it is desired to make the whole instrument; so some other driving means are required. The recently developed N.A.C.A. racket motor [3] fulfils the requirements of small size and a low, constant speed. It has the distinct disadvantage, however, of requiring a separate motor-driven commutator of considerable bulk, and of using a rather large current. However, after much experimental work a very small and simple substitute for the commutator was evolved which proved satisfactory and gave in combination with the motor sufficient power with a total consumption of only 0.10 amp. This makes the driving mechanism so small as to practically uninfluence the design.

In order to accurately measure accelerations with frequencies up to twenty vibrations per second, it is necessary to have a spring frequency of 50 to 100 vibrations per second. This means a maximum deflection of the spring of only a few thousandths of an inch which must be multiplied to one inch on the film. Optical methods of multiplying and recording have been found the only means to successfully accomplish this.[4] With careful design and workmanship the required accuracy can be obtained in recording the motion of the spring.

A spring of the type described above has not nearly enough air damping to give accurate readings.[5] This lack of damping may increase the maximum readings 10 to 30 per cent. above their true value. At first, attempts were made to damp electromagneti-

[3] "An Impulse Motor for Driving Recording Instruments," W. F. Joachim, JOUR. FRANK. INST., Aug., 1923.

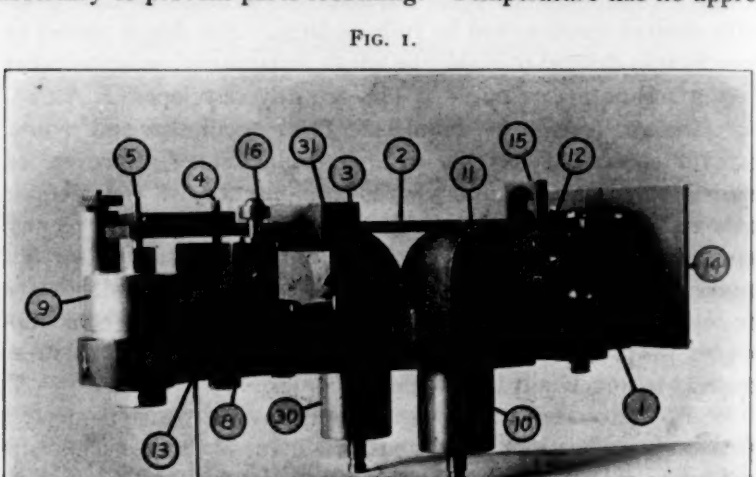
[4] "Photographic Recording of Small Motions," F. H. Norton, Nat. Advisory Comm. for Aeronautics, T. N. No. 22.

[5] "Accelerometer Design," F. H. Norton and E. P. Warner, Nat. Advisory Comm. for Aeronautics, Report No. 100.

cally, but the effect was far too small with any reasonable size of magnets. Next an oil dashpot was used with success as far as damping went, but it was rather unsatisfactory in regard to adjustment, neatness and temperature effects. However, nothing better has yet been devised.

The instrument is made to withstand vibrations and accelerations by having all parts short and stiff and by balancing all moving parts. Set screws and lock nuts are provided where necessary to prevent parts loosening. Temperature has no appre-

FIG. 1.



ciable effect on the instrument due to the proper selection of materials, except in changing the viscosity of the dashpot oil. This variation is undesirable and must be corrected at times by changing the grade of oil.

There should be simple means provided for making the following adjustments:

(*a*) the sensitivity,
(*b*) the zero position,
(*c*) the reference line,
(*d*) the damping,
(*e*) the brightness of the light source,

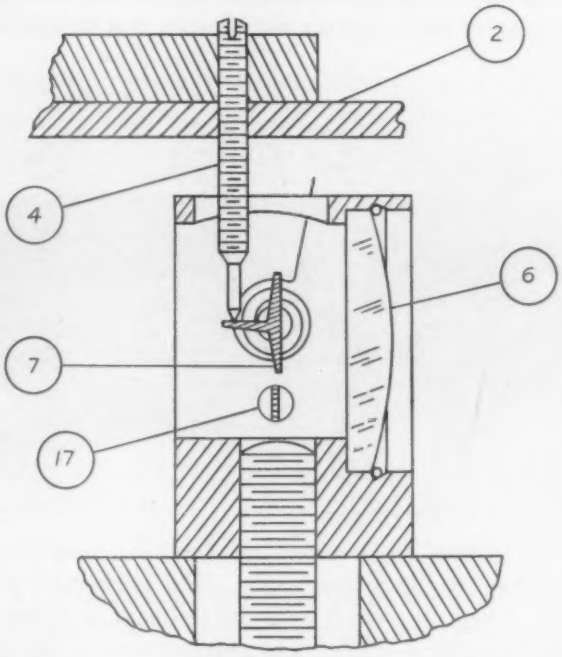
and there should be a convenient way of changing the film and

for replacing burned-out lamps. Also all working parts, such as pivots and contacts, should be easily adjustable.

Ruggedness can be attained by mounting the parts of the instrument in a strong and simple case having a minimum of projections.

The dependability is mainly due to soundness of the design and can only be estimated after extensive use under various conditions.

FIG. 2.

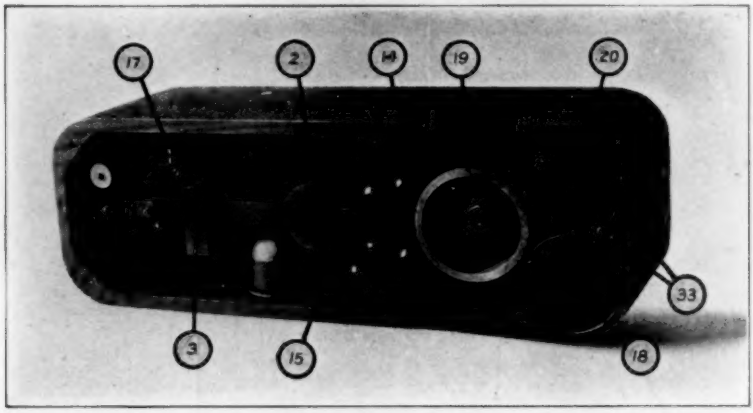


Turning now to the actual design, the first problem is the arrangement of the various parts in the most compact manner and yet with no sacrifice of accessibility. As this type of instrument must have a strong and simple case surrounding all parts, it was decided to use a strong cast-aluminum case with rounded corners divided into two compartments by a horizontal floor. Screwed-on covers allow access to either compartment. In the upper and larger compartment was placed the accelerometer unit and film drums; in the lower, the converter, driving motor and all electrical connections.

The accelerometer spring, dashpot and recording mechanism were mounted on a cast-iron base so that all adjustments to the optical system or dashpot could be made outside of the case. The unit could then be slipped in place and fastened with three screws. The motor and converter were also made as units for easy removal.

The accelerometer unit is shown in Fig. 1. The cast-iron base (1) is a rigid support for the flat cantilever spring (2). This spring carries the mass (3), the stylus (4) and the dashpot stem (5). Under the influence of vertical accelerations the spring will deflect and carry the stylus up and down a few thousandths of an

FIG. 3.



inch. This motion is converted into rotary motion of the mirror (7) supported by the pivots[6] (8). The horizontal platform of the mirror is kept in contact with the stylus at all times by a hair-spring on the mirror staff. The construction of this portion of the instrument is shown more clearly in Fig. 2. The dashpot stem carries a vane at its lower end and this moves in, but does not touch the dashpot (9) filled with oil.

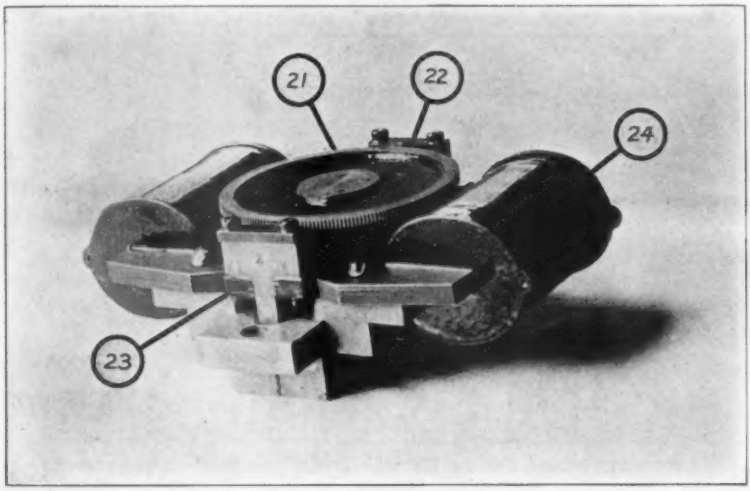
The main light source is a flashlight bulb mounted in the holder (10). The red window (11) is used to inspect the lamp. A hole on the back side of the lamp-house allows a beam to strike the plane mirror (12) from which it is reflected through a lens (6) in the face of the block (13) onto the moving mirror (7). From

[6] "The Efficiency of Small Bearings in Instruments of the Type Used in Aircraft," F. H. Norton, Nat. Advisory Comm. for Aeronautics, Report No. 94.

here it is reflected back through the same lens and is brought to a focus in the plane of the film which is just behind the slit (14). This slit limits the width of the image to a point where it would otherwise be a horizontal line. The auxiliary slit (15) cuts down extraneous light and prevents a slight fogging of the film. The optical system is lengthened by the mirror (12) and a further advantage is gained by allowing the beam to enter the lens nearly parallel to the emerging beam.

As the mirrors in this instrument are of rather special con-

FIG. 4.



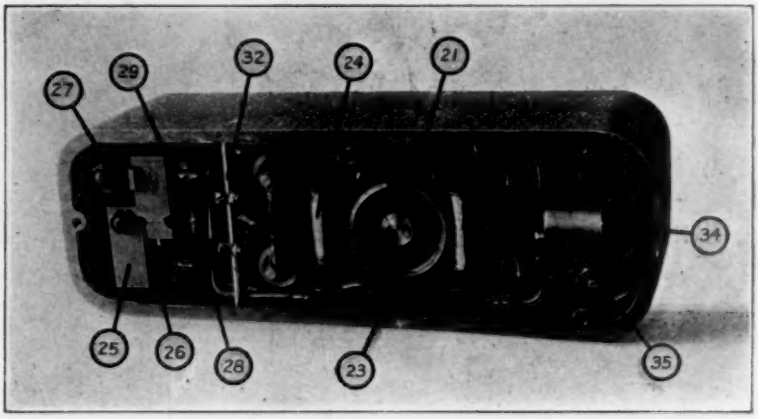
struction, it is thought that a description of them will be of interest. The moving mirror especially must be light in weight, yet rigid. A polished non-tarnishing metal was found to be the most satisfactory material. Stellite gives an excellent polish, but is very difficult to work into anything but the simplest shapes. Therefore, stainless steel was used for the moving mirror, where the shape was complicated, and stellite for the others. The polishing of the metal is much more difficult than polishing glass, as care must be taken not to polish down between the hard grains. It is better to leave a few scratches than to polish too long.

The sensitivity of the instrument can be varied in three ways: First, by changing the thickness of the spring (2); second, by moving the weight (3) along the spring (or by varying its size),

and third, by moving the block (13) along the base, thus changing the lever arm, the construction of which is made clear in Fig. 2. When the instrument is in a sensitive condition there is danger of injuring the mirror and pivots by rough handling, so the stop (16) is used to prevent too great a deflection.

To accurately measure the deflection of the image on the film, it is necessary to have some reference line. The edge of the film is not accurate enough, so a line is traced on the film by the small mirror (17) (Fig. 2). Even though the film shifts or the light source is changed, the readings will be unaffected.

FIG. 5.



The accelerometer unit shown in Fig. 1 can be completely assembled and adjusted where all parts are accessible. It can then be screwed into the case as shown in Fig. 3. The film is stored on the spool (18) which will hold nearly twenty feet of standard moving picture film. It passes around the metering drum (19) where the exposure is made, and is then stored on the spool (20) driven from the metering roll by gears and a friction clutch (35).

The film is driven at a constant rate of speed by the motor shown in Fig. 4. This motor operates in the same way as the racket motor developed by the National Advisory Committee for Aeronautics.[7] The racket wheel (21) is rotated by the pawls (22) on the armature (23), which is oscillated by the mag-

[7] "An Impulse Electric Motor for Driving Recording Instruments," W. F. Joachim, JOUR. FRANK. INST., Aug., 1923.

nets (24). The motion is discontinuous but due to the slight flexibility of the connecting mechanism between the motor and the film drum, the motion of the film is practically continuous. The characteristics of the motor used in this instrument are given in Table I.

TABLE I.

Weight	.4 lb.
Length	3.0 in.
Width	2.0 in.
Height	1.0 in.
R. P. M.	13.5
Normal current at 6 volts	0.11 amp.
Maximum H. P. at 6 volts	.000060
Efficiency at full load	6.8%

This type of motor was selected because of its small bulk and weight, its low and constant speed and its relatively very high efficiency. In this instrument the original converter has been simplified as shown in Fig. 5; (25) is a weight mounted on the spring (26) so that it may oscillate about its centre of gravity. It is caused to oscillate regularly by the magnet (27) in the manner of an electric bell or tuning fork, the current being interrupted by the contact (28). When this converter is placed in series with one of the motor coils the desired type of current results. To obtain the opposite phase for the second motor coil the contact (29) is used. The wiring diagram in Fig. 6 will make this clear.

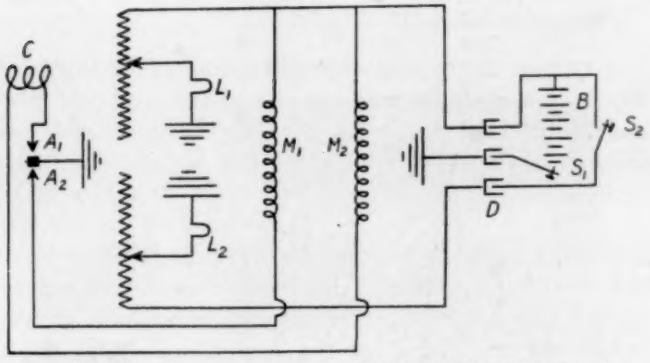
This combination of motor and generator maintains a constancy of speed of 1 per cent., the variation being due mainly to the wearing of the converter contacts. If it were possible to use a larger weight on the converter a much more constant speed could be obtained. It was feared at first that accelerations and vibration would effect the converter, but by carefully balancing the weight about its point of rotation the effect of linear accelerations was eliminated while no ordinary angular acceleration is large enough to cause irregular running.

In many cases it is quite necessary to know just what event corresponds to a given feature on the record. For example, in studying the acceleration of a man walking, it is desirable to know whether a certain peak comes when the toe or the heel strikes the ground. It has been found that the most satisfactory way to do this is to project a bright image of the slit (14) onto the film, thus forming a sharp vertical line across the film. This is accomplished

by use of the timing light (30) (Figs. 1 and 3), which throws a beam onto the mirror (31), where it is reflected to the film. The mirror is used so that the light will come from substantially the same direction as the recording light in order to avoid paralax. The timing light is connected by a separate circuit to a push button as shown in Fig. 6. Both lamps in the instrument are connected in series with the two adjustable rheostats (32) in order that the intensity of the light may be varied to suit the condition of use.

As an instrument of this type receives rough handling, the case has been designed with rounded corners and a durable finish.

FIG. 6.



L_1—main light.
L_2—timing light.
M_1 and M_2—motor magnets.
A_1 and A_2—converter contacts.
C—converter magnet.
D—three-wire bayonet connection.
B—five-cell flashlight battery.
S_1—main switch.
S_2—timing button.

As there are no parts that project beyond the surface of the case, it has a smooth and compact appearance.

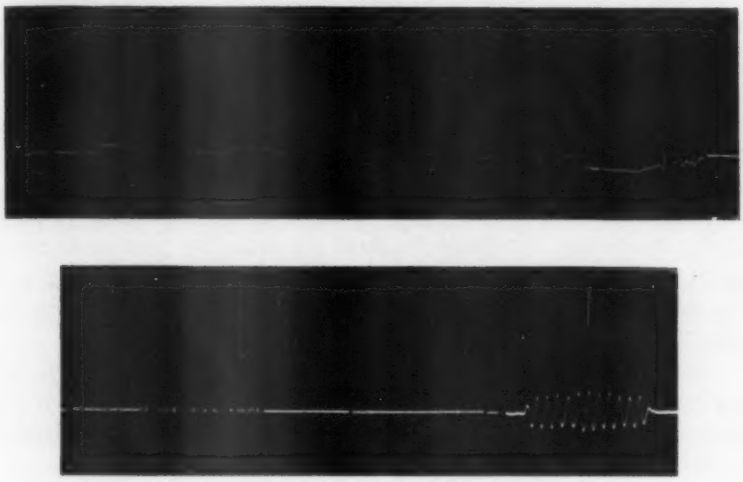
The lamp bulbs occasionally burn out and need to be replaceable without too much trouble. By removing the lower cover, loosening a set screw, and pulling off the connecting wire, the lamp holder may be removed and the lamp bulb replaced without any of the adjustments being disturbed. The film is changed in the dark-room by winding it on the storage spool, pulling it around the metering drum and starting the end in the receiving spool. In order to gain ready access to the film the upper cover of the instrument is made in two parts, the part over the film being held by the catch (33).

The overall dimensions of the accelerometer are 8¼ by 2¾ by 2¾ inches, which allows it to be carried in the coat pocket

or mounted in a very small space. The flashlight batteries to supply power require even less room. The weight of the instrument is rather large (5.0 lb.) in order to stabilize it and to prevent secondary vibrations from disturbing the readings.

The mounting of the accelerometer is very important if accurate results are desired. When it is required to measure all the acceleration acting, that is, the small tremors and vibrations as well as the large accelerations, the instrument should be mounted directly on the structure. On the other hand, if it is desired to

FIG. 7.



measure the large slow-acting accelerations (as in the case of airplanes), which would otherwise be masked by the engine vibrations, the instrument must be mounted on an elastic mounting, preferably of sponge rubber.

In Fig. 7 are shown some records made by this instrument, reproduced full size. It has been found impossible to form a very narrow line while using a mirror of sufficient size to give a satisfactory exposure with the normal voltage of the lamp.[8] The effect of using a small mirror can be seen in the reference line, but here the exposure is too small to record rapid motion. By a suitable adjustment of the optical system, however, a line is produced having a distinct central marking about one-sixth the width of

[8] "Optical Recording of Small Motions," F. H. Norton, Nat. Advisory Comm. for Aeronautics, Tech. Note No. 22.

the whole line. The middle of this central line can be estimated easily to 0.01 mm., which is more closely than needed for these measurements.

The accelerometer is calibrated easily for small accelerations by taking a record right side up, on the side and upside down, giving 1, 0 and −1 g., respectively. For larger accelerations it is necessary to mount it on a whirling table, where any desired acceleration can be produced.

This type of instrument has been so designed that it can be converted with very little change to record other quantities. For example, pressure or air-speed can be measured readily by placing a diaphragm capsule in the case in place of the accelerometer dashpot and mirror. Also two or three simultaneous records can be made on a wider film, by extending the height of the case to accommodate longer film spools. The power of the motor can be increased readily by simply reducing the resistance of the magnets with heavier wire.

The accelerometer has been used to study a number of interesting problems. Perhaps its first use was the measurement of loads on the wings of an airplane when manœuvring, the load on the wings being approximately the weight of the airplane multiplied by the acceleration acting normal to the wings.

Recently the accelerometer has been shown to record the riding qualities of automobiles apparently with considerable accuracy. It is useful in studying the spring suspension, shock absorbers, tires and cushions.

The accelerometer also will record shocks, jars, and tremors. For example, tremors in a building due to distant traffic can be measured and the vibrations of a bridge have been studied.

The accelerations of a man walking, running and jumping have been recorded and show some very interesting results.

Fire Sweeps 2500 Acres with Startling Rapidity. (Clip Sheet, U. S. Department of Agriculture, No. 315, July 7, 1924.)—Caused by a camp fire left smoldering by careless recreation seekers, the recent forest fire in the Arapaho National Forest, Colorado, swept 2500 acres of excellent pine timber in three and one-half hours, according to forestry officials of the department.

A high wind caused the fire to jump into the crowns of the trees despite the fact that officers of the forest service, with a force of 250 men, began fighting the blaze almost as soon as it started.

NOTES FROM THE RESEARCH LABORATORY, EASTMAN KODAK COMPANY.*

KNOWNS AND UNKNOWNS IN THE THEORY OF DEVELOPMENT.[1]

By S. E. Sheppard and F. A. Elliott.

A CRITICAL consideration of the sensitometric, microscopic, and physico-chemical aspects of the subject. Neither of the simple assumptions that rate of development is determined primarily (1) by the rate of chemical reaction between the silver halide and the reducer, or (2) by the diffusion processes involved, is adequate to account for the sensitometric data available. A tentative hypothesis of the mechanism of the development process is based on the assumption of selective adsorption of the reducing agent by the silver halide grains. This adsorption may be assumed to be followed by an intramolecular oxidation-reduction reaction, which is catalyzed by the latent image. The rôle of alkalies in development is intimately related to the action of the hydroxyl ion, which probably exercises a determinative influence upon the equilibrium between the polar (strongly adsorbed) and non-polar (less active) tautomeric modification of the reducing agent.

CORROSION OF MONEL METAL IN PHOTOGRAPHIC SOLUTIONS.[2]

By J. I. Crabtree and G. E. Matthews.

FOR photographic processing apparatus receiving intermittent use, Monel metal is quite satisfactory, but if the alloy is exposed continuously to strong acid-fixing solutions, especially at high temperatures and in electrical connection with other metals, serious corrosion takes place. The corrosion appears as a pitting and not as a uniform dissolution of the metal. Only temporary protection from corrosion is given by surface deposits of metallic sulphides

* Communicated by the Director.

[1] Communication No. 183 from the Research Laboratory of the Eastman Kodak Company and published in *Trans. Farad. Soc.*, 19: 355, 1923.

[2] Communication No. 202 from the Research Laboratory of the Eastman Kodak Company and published in *Ind. Eng. Chem.*, 16: 671, 1924.

due to the presence of colloidal sulphur in the solution, or by silver deposited electrolytically from an exhausted fixing bath. Physical strains produced by maltreating the alloy do not cause segregation of the corrosion in the area thus partially fatigued. More rapid corrosion occurs at the air-line than below the surface of the solution; this is largely due to convection currents which produce a more complete renewal of the solution in contact with the alloy in this air-line region, and to an increase in concentration of the solution caused by evaporation at the air surface.

THE SIZE-FREQUENCY DISTRIBUTION OF GRAINS OF SILVER HALIDE IN PHOTOGRAPHIC EMULSIONS AND ITS RELATION TO SENSITOMETRIC CHARACTERISTICS. VI.—PHOTOGRAPHIC DENSITIES DERIVED FROM SIZE-FREQUENCY DATA.[3]

By E. P. Wightman, A. P. H. Trivelli and S. E. Sheppard.

THE size-frequency distribution of a Seed lantern emulsion has been determined, and it was found that neither the simple exponential nor the Gaussian type of equation would fit it. A more satisfactory equation was found which fits very accurately. This equation, $y = Ae^{-k(\ln x - \alpha^2)}$, results from the assumption that the growth of the particles in the emulsion is proportional to their size (surface or, less accurately, their projective area) at any moment. The formation of a photographic emulsion on the basis of this assumption seems to be a very reasonable one and the authors accept it as true for a number of cases. It is shown why an equation of the same fundamental form can be used to represent both uniform diameter and uniform projective area classification. A method of determining density values from size-frequency data was worked out and consists in converting the size-frequency to projective area distribution. Then, by applying a factor for the increase in size of the silver halide grain on development, the area distribution of developed grains is found, and finally the complete density D is calculated by means of the equation

$$D = \log_{10} \frac{1}{1 - (r_1 n_1 x_1 - r_2 n_2 x_2 - \ldots r_n n_n x_n)}$$

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[3] Communication No. 200 from the Research Laboratory of the Eastman Kodak Company and published in *J. Phys. Chem.*, **28**: 529, 1924.

where r_1, r_2, *etc.*, are the expansion ratios, n_1, n_2, *etc.*, are the frequencies of grains of each class-size per unit area of plate, and x_1, x_2, *etc.*, are the mean class-sizes. A comparison of the synthetic density curve found in this way, with the curve obtained by means of the thalofide cell densitometer, shows poor agreement. Possible explanations of this are given.

Asbestos and Mercury in 1923.—The production of asbestos in 1923 was 310 short tons to the value of nearly $25,000. This, although larger than the output of 1922, is far below that of some previous years. The source is principally chrysotile, all of which is mined in California and Arizona.

The mercury production also improved in 1923, California furnishing 69 per cent. of the total United States output. The price declined considerably during the past year, but early in the present year improved notably. If a price of about $70 per flask can be maintained, a further increase of output is probable. A new mercury boiler designed by W. L. R. Emmet is about being tried, and if it is as successful as its promoters believe, an increased demand will develop, but this is not expected immediately. Should the invention become actively used, mercury will have to be imported to supplement the home supply. The above data are taken from a circular (17,291) of the Department of the Interior, U. S. A. H. L.

Employment of an Optical Illusion in the Study of Prehistoric Rock Sculptures. MARCEL BAUDOUIN. (*Comptes Rendus*, June 2, 1924.)—Let a group of cavities in a rock be photographed on a plate whose plane is about parallel to the face of the rock. The positive prepared from this plate shows the hollows as hollows, as would be expected. After one has looked at the print, let him close his eyes a moment, turn it through 180° and then look again at it. He will be surprised to see that now the hollows have become projections, and the projections have transformed themselves into depressions. The effect is ascribed to the play of shadows in the picture. The effect comes with either one or with both eyes open. The position of the light illuminating the print makes a difference. It should be to the right or to the left according to circumstances. Sometimes the effect is obtained by turning through a right angle only.

When, by the prescribed rotation, the cavities have turned into projections, there is a marked advantage for close study of the cavities, for the tiny scratches that were previously likely to escape observation have become quite visible ridges. The eye can more readily distinguish projections than depressions, and in like manner it is found that there is decided advantage in making an impression of a hollow, since the sensitive finger-tip can better discern a ridge than a scratch. G. F. S.

Is the Conception of Entropy Really Very Abstract? L. DECOMBE. (*Comptes Rendus*, Feb. 18, 1924.)—"The theories of Gibbs and of Boltzmann define entropy as the logarithm of the probability that a material system shall be found in a specified state. The very special mathematical character of this definition has caused it to be said and to be repeated that entropy is an exceedingly abstract conception." However, in the interpretations of entropy given by Clausius and by Poincaré the idea of probability does not enter, but these simpler conceptions seem to have been largely overlooked.

The author presents a sort of scientific allegory with the desire of showing entropy to be less complex than it is commonly held to be. On a plain let there be scattered at long intervals a considerable number of sheep. To an aviator the idea of a flock would not be suggested. Let the dogs at the command of the shepherd herd the animals together. Now the flock has come into being and the aviator sees a whitish patch, even if he cannot distinguish the individual sheep. The surface of the flock has for him all the properties that entropy possesses for a physicist who is studying the controllable, external modifications of a substance, while unable to perceive either the separate elements composing it or their motions. According to the activity of the dogs the area will be greater or less (variation of entropy under external forces). The sunshine will affect the sheep, diminishing or increasing their restlessness so that the area will change (increase of entropy with variation of temperature). If two flocks are united the resulting area is the sum of the two previous areas (variation of entropy with mass, additive properties of entropy). The flock may move so slowly over the plain as to give the dogs time to keep the configuration as prescribed (reversible transformation) or it may travel so rapidly that the dogs cannot keep it in shape (irreversible transformation). "Finally the dispersion of the flock under the action of sudden fear is the picture of an explosive reaction."

"It is very evident that it will not do to identify entropy with a surface or a volume, but the comparison employed suffices to make us understand (1) that, just as a given number of sheep does not always make a flock, so any system of material points does not of necessity possess the properties which the idea of entropy implies; (2) that accordingly it is not sufficient merely to consider any system of material particles in order to get an interpretation of the principles of thermodynamics. It is above all essential to have an expression for the fact that the system really possesses entropy." G. F. S.

Output of Fuller's Earth.—A large output of this material is reported by the United States Geological Survey, coming from Alabama, Florida, Georgia and Illinois, the total quantity being nearly 150,000 short tons. Coincidently to the increase of local supply in the last few years the imports of the material have declined very much. Florida is the most abundant producer. H. L.

NOTES FROM THE U. S. BUREAU OF MINES.*

MICROCHEMICAL DETERMINATION OF ORES.

By Ernest E. Fairbanks.

MICROSCOPIC methods have proved to be valuable assets in the study of low-grade ores. While the chemical assay usually discloses the total content of valuable metals in such an ore, a thorough knowledge of the nature of the ore should form the basis from which to prepare an efficient means of recovery. In the treatment of low-grade ores, inefficient recovery is too frequently the rule. In much of this material the minerals are so finely disseminated and intermixed that identification even by microscopic methods is difficult.

The application of microchemical qualitative analysis with the aid of a new device developed by the writer, should solve many of the problems of identification encountered in the study of low-grade potential ores. In these ores, the limitations of ordinary microscopic methods are so great that resort to microchemical qualitative analysis becomes indispensable. There are many ores, for example, goldfieldite, in which the individual minerals could be determined from the study of polished sections providing consistent tests, free from the suspicion of having been influenced by electrolytic action, could be obtained indicating well-established species.

With devices hitherto in use, serious difficulty is experienced in obtaining a small amount of uncontaminated material from a disseminated mineral. The writer has developed a small boring device, for obtaining drillings to be used in microchemical analysis. It is an adaptation of the microsclerometer described by Jaggar as long ago as 1897. It consists of a diamond drill, driven by a friction drive. The base is fastened to the microscope. By means of micro-adjustments the diamond point may be perfectly centred in desired position. Further details will be found in Serial 2613 of the Bureau of Mines.

* Communicated by the Director.

SAND BLAST SAND.

By W. M. Weigel.

THE use of the sand blast has increased rapidly during the past few years. It was formerly used almost entirely in the foundry to clean and remove inequalities from rough castings. This is still the most important application, but in addition, it is now employed for the removal of paint from old surfaces, carving and engraving on stone and marble, glass cutting, cleaning or renovating the walls of stone and brick buildings that have become discolored, preparing the surface of metals for the electrolytic bath, putting the final finish to metal surface, and has even been proposed as a means of channelling or cutting out blocks of stone in the quarry.

The writer has recently completed a study of the grades, shape of grains, sizes, use, and method of mining and preparation. It was found that great variation exists in the different grades as marketed, and that closer sizing and more uniformity in practice is desirable. Further information is given in Serial 2615.

SAVING GASOLINE AND INCREASING MILEAGE BY PROPER CARBURETOR ADJUSTMENT.

By G. W. Jones and A. A. Straub.

THE results of tests by the bureau have shown that the average motor vehicle wastes approximately 30 per cent. of the heat value of the fuel used.

Tests were made on high-test and low-test gasolines and a benzol-gasoline blend, in order to determine the effect on carburetor adjustment when a change is made from one fuel to another without changing the carburetor setting, also to note the effect of using preheated air.

The tests were made with a 6-cylinder, 1922 model, touring car.

Results showed that the preheater should be used only when necessary—that is, only with gasolines which will not give satisfactory operation without preheated air, during cold weather, or for the first half-hour after the engine has been started and before it is thoroughly warmed.

On changing from a low-test gasoline (specific gravity, 0.73) to a high-test gasoline (specific gravity, 0.71), the carbure-

tor should be adjusted for a correspondingly leaner mixture, otherwise the mileage will be decreased. On the other hand, if a high-test gasoline has been used and the user changes to a low-test gasoline, the carburetor setting must be changed to a richer adjustment.

In order to get the maximum mileage from benzol fuels the carburetor should be set at a leaner adjustment than that for ordinary gasoline.

The reader will find fuller details in Serial 2616.

THE ELECTROTHERMIC METALLURGY OF ZINC.

By B. M. O'Harra.

THE peculiar physical and chemical properties of zinc have delayed such immense advances—large smelting units, high recovery, low-unit costs, and ability to treat low-grade ores—as have been made in the metallurgy of lead and copper.

The retorts are heated externally by coal, natural gas, or producer gas to a temperature of 1200° C. or more. The zinc oxide is reduced to zinc, which is volatile at this temperature, and passes into a conical fire-clay condenser attached to one end of the retort, where it condenses to liquid zinc and is removed. Twenty-four hours are required for distillation, and because of the low heat conductivity of the retort walls and of the ore charge itself, the heat efficiency even of the most modern regenerative furnaces is only about 12 per cent. The retorts have a short life, thirty to sixty days, at the high temperature required; zinc losses are heavy, usually 10 per cent. or more; and the proportion of impurities in the retort charge must be carefully controlled to prevent the rapid corrosion of retorts.

Because of the imperfections of the retort and electrolytic processes and the promise that the electric furnace offers in overcoming these imperfections, the United States Bureau of Mines, in coöperation with the Missouri School of Mines and Metallurgy, conducted a study of the electrothermic metallurgy of zinc.

It was found that conditions being equal, the electrothermic process may be said to have the advantage over the electrolytic process in the items of power, labor, metal recovery, cost of roasting, first cost of plant, and in its adaptability to smaller scale operations; and over the retort process in the items of reduc-

tion, fuel, labor, metal recovery, ability to treat low-grade and impure ores, cost of roasting, first cost of plant, and cost of retorts and condensers.

The electrothermic smelter must be near cheap power, as must also the electrolytic, but as many retort smelters are now some distance from their supply of ore this is no great difficulty. Each of the three processes—retort, electrolytic, and electrothermic—has its particular field and there are undoubtedly places in this country where the electrothermic process could be profitably applied. A more complete discussion is presented in Bulletin 208 of the Bureau of Mines.

Third Pan-American Scientific Congress to Assemble at Lima, Peru.—On December 20th next, the Third Pan-American Scientific Congress will assemble at Lima, Peru, and will continue in session for two weeks. The Organizing Committee is now actively engaged in making arrangements for the Congress, and Coöperating Committees in the different Republics of the American Continent are also engaged in arousing interest among the scientific and educational institutions of the respective countries in the forthcoming meeting.

Prior to 1908 congresses of a scientific character had been held at irregular intervals at which only representatives of the Latin-American Republics were present, but in that year the First Pan-American Scientific Congress assembled at Santiago, Chile, at which nineteen republics, including the United States, were represented. The Second Congress was held at Washington in 1915-16, at which delegates from all the American Republics were in attendance.

Can Trees Inherit Characteristics Induced by Environment?—A study to determine whether a tree species that has grown under different climatic conditions in two widely separated regions will continue to exhibit the influences of environment when the seed is planted in a third region alien to both the others is being undertaken by the Northeastern Forest Experiment Station of the United States Forest Service in coöperation with the Forestry Department of the Massachusetts Agricultural College, Amherst, Massachusetts.

Seedlings of Scotch pine from seed procured near Riga on the Baltic Sea, and from Austrian seed, have been planted in equal quantities at the rate of 1000 seedlings to the acre on the Mt. Toby College Forest in Massachusetts. The seedlings are two years old and have been planted at 6.6-foot intervals each way. It is believed that Scotch pine grown from seed obtained from the Baltic provinces will have straighter, cleaner trunks, therefore yielding lumber of a higher quality than that of the trees of Austrian origin. Periodic observations will be made of the plantations to determine the relative desirability of the stock for extensive forest planting in the Northeast.

NOTES FROM THE U. S. BUREAU OF CHEMISTRY.*

HASTENING THE COLORATION OF LEMONS.[1]

By F. E. Denny.

[ABSTRACT.]

SOME commercially mature lemons are green in color when picked. The desired yellow color must be secured by subsequent treatment.

The change from green to yellow is hastened by the use of the combustion gases that arise from kerosene stoves during the burning of kerosene. An investigation was conducted in the Bureau of Chemistry to determine the identity of the gaseous constituent responsible for the coloration of the fruit.

After the mixture of gases from a kerosene stove had bubbled through Pettenkofer tubes filled with bromine water, the residual (unabsorbed) gas failed to induce coloration. This suggested that the effective constituent must be among the unsaturated hydrocarbons.

Ethylene, even in low concentration, caused green lemons to turn yellow. Fruit colored in this way differed in no way from similar fruit colored in the usual way with kerosene stoves. However, attempts to isolate ethylene from stove gas were unsuccessful.

When mixed with air in varying proportions by volume, concentrations of ethylene down to 1 to 200,000 colored lemons in five to eight days. Concentration down to 1 to 2,000,000 required six to ten days. The lowest concentration tried (1 to 5,000,000) required about fourteen days, indicating that this concentration represents the highest dilution at which the rate of coloring is markedly influenced. High concentrations appear to retard coloring, since 80 per cent. ethylene for seven days gave only slight coloring.

Absence of oxygen prevented coloration of the fruit by ethylene.

* Communicated by the Chief of the Bureau.

[1] Published in *J. Agr. Research*, **27** (March 8, 1924) : 757.

Coloration was not measurably hastened by ethylene at a temperature of 45° F., but the rate of coloring increased with increasing temperatures from 57° to 82°. A reduction in rate, however, was observed at 93°.

Both ethylene and stove gas increased the rate of respiration of lemons. The carbon dioxide output was increased about 150 to 250 per cent.

NOTES ON AMYL NITRITE.[2]

By L. F. Kebler and W. F. Kunke.

[ABSTRACT.]

Two different makes of amyl nitrite were submitted to fractional distillation. From the range of temperatures found it is evident that the amyl nitrites tested contained considerable quantities of substances boiling below and above the recognized boiling range for amyl nitrite. To what extent such mixtures would differ therapeutically from amyl nitrite boiling within a definite recognized range is a matter that should be considered.

CLARIFICATION OF YEAST EXTRACTS WITH NEUTRAL LEAD ACETATE.[3]

By F. W. Reynolds.

[ABSTRACT.]

A MEANS has been devised for shortening the purification and concentration of enzyme-containing yeast extracts reported in *Industrial and Engineering Chemistry* (vol. 16, p. 169).

Efficient clarification of such extracts was accomplished by using comparatively small quantities of lead acetate—only enough to produce a flocculent, easily filtered precipitate, followed by washing on the ultra-filter. A little of the lead precipitate, washed free from soluble material, is an excellent filtering medium for the removal of the turbidity or opalescence which may develop in yeast extracts after concentration and washing on an ultra-filter.

[2] Published in *J. Am. Pharm. Assoc.*, 13 (May, 1924) : 439.

[3] Published in *Ind. Eng. Chem.*, 16 (June, 1924) : 562.

THE ACTIVE ACIDITY OF SOILS.[1]

By Edgar T. Wherry.

[ABSTRACT.]

ACTIVE acidity and alkalinity are important in connection with the growth of plants, both directly and indirectly. They may be directly toxic in high concentrations and indirectly toxic through affecting the solubility of iron and aluminum. They also exert a marked influence on the activities of various soil organisms, both beneficial and injurious. In the writer's opinion, no soil survey can be regarded as complete without including determinations of the reaction in terms of active acidity or alkalinity. Both electrometric and color-comparative methods of determining active acidity have inherent defects, but when care is taken to avoid errors of manipulation, the two methods give accordant results. The second of these is the simpler, and a convenient apparatus for applying it in the field is now available.

Data on Structural Material.—Values of the strength of pure metals and their alloys, and of wood are given in the revised edition of the Bureau of Standards circular on the physical properties of materials. The data include the strength in tension, compression, and shear, the resistance to fatigue, and many other properties which an engineer must know in order to design a structure that will safely carry its intended load. The effect of high temperatures on the strengths of different metals is shown by tables and by graphs, and the physical properties such as specific gravity, melting point, and coefficient of expansion are given.

The information given is compiled from various sources, including tests made at the Bureau of Standards. The data on wood are taken from Bulletin 556 of the United States Forest Service, Department of Agriculture. The data are given in Circular 101 of the Bureau of Standards, entitled "Physical Properties of Materials." Copies may be obtained from the Superintendent of Documents, Washington, D. C.

Talc and Soapstone.—The Department of the Interior reports that the total quantity of talc and soapstone produced in the United States in 1923 was nearly 170,000 short tons. The output represents a decrease of about 1 per cent. as compared with 1922, but prices were higher. Unlike the supply of Fuller's earth, which is mostly from the southern states, talc and soapstone are mined in the northern regions. H. L.

[1] Published in *J. Wash. Acad. Sci.*, 14 (May 19, 1924) : 207.

THE FRANKLIN INSTITUTE.

TO THE MEMBERS OF THE FRANKLIN INSTITUTE:

The preliminary program of the "Centenary Celebration of the Founding of The Franklin Institute and the Inauguration Exercises of the Bartol Research Foundation," which will take place in Philadelphia, September 17, 18 and 19, 1924, is printed in this issue of the JOURNAL. At the time of going to press, it was impossible to state where all of the sectional meetings will be held, but it is quite likely that they will take place in the buildings of the University of Pennsylvania.

Changes in places for the sectional meetings (as specified in the preliminary program) have been made in order to provide for a larger number of papers and a greater attendance than was originally anticipated.

Definite arrangements have already been made for the housing of the speakers and the delegates from colleges and learned societies, at the dormitories of the University of Pennsylvania.

It is hoped that all members of the Institute will be able to attend at least some of these meetings. Others, who are interested in various papers, will be admitted to any of the meetings, as guests of the Institute, in so far as the accommodations of the various rooms will permit.

A final program will be printed in the September number of the JOURNAL. In this program the title, time and place of every address will be scheduled.

WM. C. L. EGLIN,
President.

CENTENARY CELEBRATION OF THE FOUNDING OF THE FRANKLIN INSTITUTE AND THE INAUGURATION EXERCISES OF THE BARTOL RESEARCH FOUNDATION.

September 17, 18, 19, 1924, Philadelphia.

THE COMMITTEES OF THE CENTENARY CELEBRATION.

HONORARY COMMITTEE.

ELIHU THOMSON, *Chairman.*

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EXECUTIVE COMMITTEE.

WM. C. L. EGLIN

WALTON CLARK C. C. TUTWILER

HENRY HOWSON, *Treasurer*

GELLERT ALLEMAN, *Chairman*

The principal events of the program are as follows:

WEDNESDAY, SEPTEMBER 17TH.

9.30 A.M. Assembly of Delegates and Guests at the Hall of The Franklin Institute, 15 South Seventh Street.

10.00 A.M. Academic Procession from the Hall of The Franklin Institute to the Walnut Street Theatre. (Academic Costume is in order.)

10.30 A.M. Invocation. Reverend Louis C. Washburn, S.T.D., Rector of Christ Church, Philadelphia.

10.30 A.M. Address of Welcome. The Honorable W. Freeland Kendrick, Mayor of Philadelphia. Address: President Wm. C. L. Eglin, Sc.D. Address: Professor Elihu Thomson, Ph.D., Sc.D., Honorary Chairman of the Centenary Celebration Committee of The Franklin Institute.

1.00 P.M. Luncheon to Delegates and Guests, the Bellevue-Stratford.

2.30 P.M. Sectional Meetings: Places to be announced later.

7.30 P.M. Informal Dinners.

THURSDAY, SEPTEMBER 18TH.

10.00 A.M. Sectional Meetings: Places to be announced later.

1.30 P.M. Luncheon to Delegates and Guests, the Bellevue-Stratford.

2.30 P.M. to 6.00 P.M. Garden Party.

8.30 P.M. Open Meeting, the Academy of Music. President Wm. C. L. Eglin, Sc.D., presiding, will introduce the Chairman of the evening, the Hon. William Cameron Sproul, LL.D. Address: "The Natural and Artificial Disintegration of Elements," by Professor Sir Ernest Rutherford, Kt., M.A., F.R.S., Trinity College, Cambridge.

FRIDAY, SEPTEMBER 19TH.

10.00 A.M. Unveiling of Tablet at Bartol Research Foundation.

10.15 A.M. The Academy of Natural Sciences. Address: "The Fifth Estate," by Arthur D. Little, Chem.D., Cambridge. Address: "Stimulation of Research and Invention," by Professor D. S. Jacobus, Dr.Eng., New York City.

11.30 A.M. Sectional Meetings: Places to be announced later.

2.00 P.M. Luncheon to Delegates and Guests, the Bellevue-Stratford.

7.30 P.M. Banquet to Delegates and Guests, the Bellevue-Stratford.

SPEAKERS.

Professor Joseph S. Ames, Ph.D., LL.D., Johns Hopkins University, "Recent Developments in Aeronautics."

Professor Wilder D. Bancroft, Ph.D., Cornell University, "The Development of Colloid Chemistry."

Professor Sir William Henry Bragg, K.B.E., M.A., D.Sc., F.R.S., Royal Institution, London, "The Carbon Atom in Crystalline Structure."

Professor William Lawrence Bragg, M.A., F.R.S., Victoria University, Manchester, "Inorganic Crystals."

Professor P. W. Bridgman, A.M., Ph.D., Harvard University, Cambridge, "Some Aspects of High Pressure Research."

General John J. Carty, D.Sc., LL.D., American Telephone and Telegraph Company, "Progress in Telephony."

Professor E. G. Coker, M.A., D.Sc., F.R.S., University College, London, "Photo-elasticity."

William D. Coolidge, Ph.D., General Electric Company, "Modern X-ray Tube Development."

Director Arthur L. Day, Ph.D., Sc.D., Geophysical Laboratory, Carnegie Institution, Washington, "Some Causes of Volcanic Activity."

Professor F. G. Donnan, C.B.E., M.A., Ph.D., D.Sc., F.I.C., F.R.S., University College, London, "The Influence of J. Willard Gibbs on the Science of Physical Chemistry."

William LeRoy Emmet, Sc.D., General Electric Company, "Mercury Boiler."

Professor Charles Fabry, University of Paris, "Spectroscopy in Past and Present."

Professor F. Haber, Ph.D., Direktor, Institut für Physikalische Chemie und Elektrochemie, Dahlem, Berlin, "Technical Results of the Theoretical Development in Chemistry."

Professor W. J. Humphreys, C.E., Ph.D., United States Weather Bureau, Washington, "The Way of the Wind."

Professor D. S. Jacobus, Dr.Engr., New York City, "Stimulation of Research and Invention."

George L. Kelley, Ph.D., Philadelphia, "The Restraint of Exaggerated Grain Growth in Critically Strained Metals."

Professor A. E. Kennelly, Sc.D., Massachusetts Institute of Technology, "The Measurement of Acoustic Impedance by the Aid of the Telephone Receiver."

Dean Dexter S. Kimball, M.E., The College of Engineering, Cornell University.

Irving Langmuir, Ph.D., D.Sc., LL.D., General Electric Company, "Electric Discharges in Gases at Low Pressures."

Arthur D. Little, Chem.D., Cambridge, Massachusetts, "The Fifth Estate."

Professor C. H. Mathewson, Ph.D., Yale University, "The Trend in Physical Metallurgy."

Director C. E. K. Mees, D.Sc., Eastman Kodak Company, "Applied and Scientific Photography."

Professor Charles E. Mendenhall, Ph.D., University of Wisconsin, "Electronic Phenomena at the Surface of Metals."

Professor A. A. Michelson, Ph.D., Sc.D., LL.D., University of Chicago.

Professor Dayton C. Miller, A.M., Sc.D., Case School of Applied Science, "The Phonodeik."

Professor W. Lash Miller, Ph.D., University of Toronto, "Concentration and Polarization at the Cathode during Electrolysis of Solutions of Copper Salts."

Ralph Modjeski, Dr.Engr., Consulting Engineer, Philadelphia, "Unusual Problems Encountered in the Design and Construction of Large Bridges."

Daniel E. Moran, M.Sc., Consulting Engineer, New York City, "Some of the Effects of Loading Granular Material."

Sir Charles Algernon Parsons, K.C.B., M.A., LL.D., D.Sc., F.R.S., Newcastle-on-Tyne, "Steam Turbines on Land and Sea."

Major General Mason M. Patrick, Chief, United States Air Service, Washington, "Military Aircraft and Their Use in Warfare."

Dean Harold Pender, Ph.D., Moore School of Electrical Engineering, University of Pennsylvania, "A New Type of Non-inductive High Resistance."

F. W. Peek, A.B., General Electric Company, Pittsfield, "Lightning."

Director Charles L. Reese, Ph.D., Sc.D., E. I. du Pont de Nemours and Company, "Twenty-five Years' Progress in Explosives."

E. W. Rice, Jr., A.M., Sc.D., D.Eng., Honorary Chairman, General Electric Company, Schenectady, "The Field of Research in Industrial Institutions."

Professor Sir Ernest Rutherford, Kt., M.A., F.R.S., Trinity College, Cambridge, "The Natural and Artificial Disintegration of Elements."

Professor Albert Sauveur, Sc.D., Harvard University.

Provost Emeritus Edgar F. Smith, Ph.D., LL.D., L.H.D., Chem.D., Litt.D., M.D., University of Pennsylvania, "Early Science in Philadelphia."

Frank J. Sprague, D.Engr., New York City.

Major General George Owen Squier, Ph.D., United States War Department, Washington, "Electrical Communications for Military Purposes."

Professor Julius Stieglitz, Ph.D., D.Sc., Ch.D., University of Chicago, "The Theory of Color Production in Organic and Inorganic Compounds."

Professor Bradley Stoughton, Lehigh University, "Magnetic Analysis of Steel."

Professor W. F. G. Swann, D.Sc., University of Chicago, "The Origin of the Earth's Electric and Magnetic Phenomena."

General Harry Taylor, Chief of Engineering, United States Army, Washington, "Modern Military Engineering."

Professor Elihu Thomson, Ph.D., Sc.D., General Electric Company.

Professor John Sealy Edw. Townsend, F.R.S., New College, Oxford, "Motion of Electrons in Gases."

Professor Augustus Trowbridge, Ph.D., Princeton University.

Major General C. C. Williams, United States War Department, Washington, "Modern Ordnance."

Professor Pieter Zeeman, Ph.D., Sc.D., University of Amsterdam, "Radiating Atoms in Magnetic Fields."

MEMBERSHIP NOTES.

CHANGES OF ADDRESS.

MR. ROBERT J. ANDERSON, P. O. Box 111, Fenway Station, Boston, Massachusetts.

MR. W. M. C. KIMBER, Sword and Kimber Company, 4861 Stenton Avenue, Philadelphia, Pennsylvania.

DR. ISRAEL MAIZLISH, 53 Warren Street, Lynn, Massachusetts.

MR. C. E. SARGENT, 211 Sargent Street, Kendallville, Indiana.

MR. C. A. WILLIAMS, 119 North College Avenue, Oxford Ohio.

NECROLOGY.

THOMAS CORWIN MENDENHALL.

Thomas Corwin Mendenhall, whose life work closed on March 22, 1924, left behind him a record characteristic of the highest type of American manhood.

Born in Hanoverton, Ohio, on October 4, 1841, he received the ordinary public school education of his time, and with this as a basis made a noteworthy record in both educational and scientific fields.

In 1873 he became professor of physics and mathematics at Ohio State University, a position which he held until 1878; when he was appointed professor of physics at the Imperial University of Japan. He held this position for three years, and during this time made investigations of the force of gravity at sea level, making use of a new form of pendulum for the purpose; and made calculations on the mass of the earth.

On his return to the United States he was appointed professor of physics at Ohio State University; and in 1884 was made professor of physics, emeritus, a position he held at the time of his death.

From 1884 until 1886 he was professor of electricity with the United States Signal Corps; when he was elected president of the Rose Polytechnic Institute.

From 1889 to 1894 he was Superintendent of the United States Coast and Geodetic Survey, and during the same period was Superintendent of the United States Weights and Measures, a member of the United States Lighthouse Board, of the First Behring Sea Commission and of the United States-Great Britain Boundary Line Commission.

In 1893 he went as United States delegate to the International Electrical Congress; and in 1900 was awarded a gold medal at the Paris Exposition for his studies in electricity.

His investigations in science, particularly in the fields of physics and metrology, brought him recognition from several institutions of learning. He received the honorary degree of Doctor of Philosophy from Ohio State University in 1878; Doctor of Science from Rose Polytechnic Institute in 1887; Doctor of Laws from the University of Michigan in 1887; and the same degree from Western Reserve in 1912.

He was a member of many learned and scientific societies. Was president of the American Academy of Arts and Sciences, and of the American Metrological Society; honorary fellow of the National Geographic Society, and of

The Franklin Institute from which he received the award of The Franklin Medal in 1918. He also received a gold medal from the National Educational Society of Japan.

His book on "A Century of Electricity," written in 1886, is a clearly written account of the progress of the science and art of electricity during the century extending from the time of Franklin's experiments to those that led to the development of the dynamo, the electric light and telephone. It is a book that can still be read to advantage by those who wish to be informed on the fundamentals of the science.

THOMAS COMMERFORD MARTIN.

Thomas Commerford Martin was born in London, England, July 22, 1856, the son of Thomas and Catherine (Commerford) Martin.

He was educated in England as a student in theology, but the attractions of physical science led him into association with Thomas A. Edison upon his arrival in the United States in 1877. He severed this connection in 1879 on account of ill health, and went to the West Indies, where he engaged in journalistic work for the Government of Jamaica. Upon returning to the United States in 1880 he edited the *Operator*, and from 1883 to 1909 was editor of *The Electrical World*.

Mr. Martin was one of the founders of the National Electric Light Association, and also one of the founders of the American Institute of Electrical Engineers, of which latter body he was President in 1887–88.

He was at all times active in the many technical and welfare societies of which he was a member; editor of a number of volumes, among them the life work of Edison and the life and work of Tesla; a frequent contributor to reference books and publications on electrical subjects; an authority on the history, progress and statistics of the electrical industry; corresponding member of The Franklin Institute.

Mr. Martin died May 17, 1924, at his summer home in Massachusetts.

Mr. John C. Trautwine, Jr., 257 South Fourth Street, Philadelphia, Pennsylvania.

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BOOK REVIEWS.

EFFECT OF VARIATIONS IN THE ASSUMED FIGURE OF THE EARTH ON THE MAPPING OF A LARGE AREA. Walter D. Lambert, U. S. Coast and Geodetic Survey. Special Publication No. 100, pp. iii and 35. Washington, Government Printing Office, 1924.

This publication is the result of considerable study and labor on the part of the author in endeavoring to answer the following four questions which have been much discussed in recent years in regard to the best spheroid to use for the figure of the earth: (1) Will the best obtainable spheroid differ much from the Clarke spheroid of 1866, now officially adopted by the whole of North America? (2) If such a spheroid were adopted, would the geographic coördinates of points now referred to the Clarke spheroid be changed much? (3) Will it be necessary in the near future to give up the Clarke spheroid for geographic purposes and adopt another? (4) Are our present methods of adjusting triangulation for obtaining the figure of the earth and the deflections of the vertical adequate when extended to a territory as large as the whole of North America?

At the beginning of the paper is given a table showing the principal determinations of the earth's mean figure, starting with the work of Mechain and Delambre in 1799, and ending with that of Hayford (2) in 1909. Of the twenty-one values given, the one probably nearest the truth is that of Hayford (1) of 1909, in which the semi-major axis (a) = 6378.388 kilometres and the reciprocal of the flattening $\left(\frac{1}{f}\right) = 297.0$. These values were adopted by the Paris astronomic conference of 1911, and are used in the American Ephemeris and Nautical Almanac. This Hayford spheroid has also been officially adopted in Finland. In determining these dimensions Hayford used the deflections of the vertical corrected for topography and isostatic compensation.

Following this table is another interesting one showing the spheroids which

have been adopted for geographic purposes and the countries in which they are used.

In computing a triangulation, there are four quantities used which involve the dimensions of the spheroid adopted: (1) The correction to the azimuths for the elevations of the object sighted; (2) the correction to the azimuths to reduce from the azimuth of a vertical section to that of a geodetic line; (3) the spherical excess of the triangles; and (4) the reduction of horizontal angles from the geoid to the spheroid of reference. The author takes up each of these quantities separately and shows how much each would be effected by a change in the spheroid, and clearly points out that a change in the spheroid of reference within probable limits has almost no effect on the triangulation as ordinarily computed. It is shown, however, that in refined work, the correction for (4), that is, to a direction for the non-coincidence of the normal to the spheroid of reference with the actual plumb line is desirable, especially in mountainous regions.

The general conclusions reached by the author are: (1) That the Hayford spheroid of 1909, with correction for topography and isostatic compensation may be taken as representing our best present knowledge; (2) the only reason for changing the spheroid used for geographic purposes would be for international uniformity; (3) for ordinary geographic purposes relative directions and distances between points in North America would be little effected; (4) the labor of making the change of spheroid would be great and the advantage for purely geographic purposes practically nil; (5) in the scientific problem of the figure of the earth it would be desirable to allow for the effect of a change of spheroid on the triangulation, if the area covered by the connected scheme of triangulation were as large as North America. At the end of this discussion there are given four actual examples showing the effect of change of spheroid.

The last chapter of the publication gives an interesting development of the formulas for the computation of geodetic positions over long lines of given length and azimuth, and the development of the formulas for the inverse problem, the determination of the length and azimuth of the line between two points whose latitudes and longitudes are given. Numerical examples are given for each of these problems. This chapter is especially valuable in that the subject-matter is not easily obtained except in languages other than English.

There is probably no one in this country better fitted than the author to treat a subject of this kind. During the last few years, he has devoted considerable time to it, and no doubt his conclusions will be accepted by those scientists especially interested in spheroids of reference for mapping purposes. It is probably safe to say that if a new spheroid of reference is ever adopted for North America, it will be purely for scientific purposes. Tens of thousands of geographic positions dependent upon triangulation have already been computed on the North American datum and many of these have been published by the U. S. Coast and Geodetic Survey, the U. S. Geological Survey, and the U. S. Army Engineers. To adopt a new spheroid would necessarily change all these positions, which would not only cause inconvenience, but lead to endless confusion.

WALTER F. REYNOLDS.

STORAGE BATTERIES. A general treatise on the physics and chemistry of secondary batteries and their engineering applications, by George Wood Vinal. 402 pages, illustrations, 8vo. New York, John Wiley and Sons, Inc., 1924. Price, $4.50.

This book is comprehensive in its scope and well balanced in respect to the space given to the different parts of the subject, and is well arranged for ready reference. The author has gathered data from all the principal authorities on the subject, adding much valuable information obtained by the research work which has been carried on in the Bureau of Standards.

The introductory statement of the fundamental principles of the electrolytic cell is followed by a brief history of the art. The author then takes up in a general way the materials and methods of manufacture, and the design of the different parts of the storage battery cell-plates and their active material, separators, electrolyte and containers.

The various theories of the reactions in the cell are then presented and reasons given for accepting the double sulphate theory. This is followed by a discussion of the electrical characteristics of the storage cell and the various factors which govern them.

The latter half of the book is devoted to methods of operating, testing and repairing, and to the principal practical applications of the storage battery.

The author is to be congratulated on the elimination of many popular fallacies of long standing in regard to storage batteries and on the position he has taken with reference to the many storage battery humbugs which have been perpetrated from time to time. The numerous references and bibliographies scattered through the book will be found especially valuable by those desiring to follow up more in detail some particular branch of the subject.

The development of the storage battery industry has been so rapid and so extensive in the last decade that most of the literature on the subject is now obsolete or is in the form of scattered articles on special subjects. Mr. Vinal's book will, therefore, be welcomed by those who have sought in vain for an up-to-date and authoritative presentation of the theory and application of storage batteries.

J. LESTER WOODBRIDGE.

AMERICAN BUYERS' GUIDE. Containing sources of supply and handbook information for American buyers of central European merchandise. Edited by the Publication Committee of American Chamber of Commerce in Germany. xvii–283 pages, 8vo. American Chamber of Commerce in Germany, Berlin, 1924. Price, $3.50.

The American Chamber of Commerce in Germany occupies an office in the Equitable Building in Berlin, a picture of which is given, showing an imposing piece of architecture, not of the sky-scraper type. The present volume is the first edition, and has been prepared with the belief that it contains much valuable information for American merchants who are seeking goods from central European sources. Some embarrassment has resulted from the fluid conditions of German business, changes occurring, it is stated in the preface, faster than they could be written up. The user of the book, however.

is offered the opportunity to consult the publishing committee for exact and up-to-date information as far as it is possible to furnish the same. The committee having full confidence in the usefulness of the publication has begun on the edition for next year. There is no doubt that American merchants will find much aid in the material included.

THE PHYSICAL CHEMISTRY OF PHOTOGRAPHIC PROCESSES. A general discussion held by the Faraday Society. 406 pages, 8vo, limp cloth. Published by the Society, London. Price, 12 shillings, 6 pence.

The Faraday Society has been holding discussions on a variety of subjects, at which many prominent scientists have taken part. The volume in hand is a searching investigation into the bearings of the present knowledge of physical chemistry on photographic processes, being a collection of papers and discussions at a meeting held May 28, 1923. The general introduction was by Prof. Wilder D. Bancroft, who discussed the theory of photographic procedure, beginning with the emulsion, treating the condition of plate and grain sensitiveness, the latent image, and the developer. The list of subsequent contributors, both in papers and discussions, is a long one, and includes a number of well-known Continental authorities, among whom may be mentioned Lüppo-Cramer, Lumière and Seyewetz.

The greater portion of the subject-matter is very abstruse and it appears that the authorities were not in accord on many of the points. This is to be expected, for while the general technique of photography is now a very simple one, the theories of the processes are yet incompletely developed. Discussions of this character are of great value in elucidating the nature of the processes, and will have their effect in improving and simplifying the methods, but empirical investigations may still for some time be important and fertile means of advancing the practical applications. To the vast mass of photographers, the bulk of this book will be caviare, but this is not to be understood as deprecating in any way its value or the service rendered by the Faraday Society in arranging for the papers and discussions.

Professor Bancroft, in the general introductory, considers the nature of the latent image, the peculiar and still unsolved feature of the ordinary processes, and Toy discusses the "Mechanism of the Latent Image Formation." Bancroft rejects both the subhalide theory and the nucleus theory (that which assumes particles of metallic silver set free) and declares that the latent image is due to silver adsorbed by silver bromide. He disagrees somewhat with Mees. Toy holds that the reaction of silver bromide to light is due to minute amounts of foreign substances that have a catalytic action.

It is curious that in these studies of photographic procedures so little attention is given to the light sensitiveness of other substances. Silver halides are, of course, the only salts yet known adapted for the rapid and accurate work now demanded in photography, but it would seem that in the pure science a wider range might be taken. Mercurous iodide is fairly sensitive to light. Some experiments made by the reviewer seem to show that gelatin increases this sensitiveness. From the blackening that light produces, it seems likely that mercury is separated. Another remarkable point is that in all these official discussions on the latent image, no account seems to be taken of the fact that

the whole emulsion can be removed after exposure, so that the plate appears perfectly clear, yet a complete image can be easily obtained by a simple development procedure. The ordinary method of accomplishing this is by precipitating a mercury layer. This layer may in a year or so evaporate, but the impression remains and immersion for a short time in the mercury developer will restore the image. Does the latent image reside on the gelatin?

Although this symposium is, as usual, mainly devoted to the study of the phenomena of the silver halides, a departure is made in a paper by Jacques Errera, of Brussels, in a record of investigations as to conditions of sensitiveness of asphalt films. The sensitiveness of certain natural hydrocarbons, especially the bitumen of Judea, is especially interesting to photographers, as it was the material used by Niépce to produce the first picture that can be claimed as an actual photograph. The details of this work were set forth briefly in a paper by the present reviewer, published in this JOURNAL in 1923. Errera quotes from Kayser's researches (published in 1879) that by treatment of the asphalt successively with boiling alcohol, ether and chloroform, three portions are obtained of which the last is alone sensitive to light. Errera's investigations lead to the view that the condition of this sensitive portion is that of a complex colloid. HENRY LEFFMANN.

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS. Report No. 186, The Application of Propeller Test Data to Design and Performance Calculations, by Walter S. Diehl. 11 pages, illustrations, quarto. Washington, Government Printing Office, 1924.

This report is a study of test data on a family of Durand's propellers (Nos. 3, 7, 11, 82, 113, 139), which is fairly representative of conventional design. The test data are so plotted that the proper pitch and diameters for any given set of conditions are readily obtained. The same data are plotted in other forms which may be used for calculating performance when the ratio of pitch to diameter is known. These new plots supply a means for calculating the performance, at any altitude, of airplanes equipped with normal or supercharged engines.

The coefficients used and the methods of plotting adopted in this report coördinate the results of a few tests into complete families of curves covering the entire range of p/D ordinarily used. This method of analyzing test data enables an investigator to plan tests systematically and leads to useful application of test data.

PUBLICATIONS RECEIVED.

Storage Batteries. A general treatise on the physics and chemistry of secondary batteries and their engineering applications, by George Wood Vinal. 402 pages, illustrations, 8vo. New York, John Wiley and Sons, Inc., 1924. Price, $4.50.

Canada, Department of Mines. The Mineral Industries of Canada, compiled by A. H. A. Robinson. 138 pages, illustrations, maps, 12mo. Ottawa, Department, 1924.

Faraday Society. Electrode Reaction and Equilibria. A general discussion held November, 1923. 75 pages, illustrations, tables, 8vo. London, Faraday Society, 1923. Price, 10 shillings, 6 pence.

First (Experimental) Report to the Atmospheric Corrosion Research Committee (of the British Non-ferrous Metals Research Association), by W. H. J. Vernon. Presented to the Faraday Society, December 17, 1923. 95 pages, illustrations, plates, 8vo. London, Society, 1924.

National Advisory Committee for Aeronautics. Technical Notes, No. 196, Remarks on the Pressure Distribution over the Surface of an Ellipsoid, Moving Translationally through a Perfect Fluid, by Max M. Munk. 8 pages, quarto. No. 197, Some Tables of the Factor of Apparent Additional Mass, by Max M. Munk. 7 pages, illustrations, quarto. Washington, Committee, 1924.

U. S. Department of Commerce, Bureau of Standards. Large Mollier Chart (Foot-Pound-Fahrenheit Units), Properties of Ammonia, 16 x 40 inches. Washington, Government, 1924.

American Buyers' Guide. A classified directory and handbook for American importers and exporters, 1924–1925. 296 pages, illustration, portrait, 8vo. Berlin, The American Chamber of Commerce in Germany, 1924.

American Engineering Standards Committee. Year Book, 1924. 64 pages, quarto. New York, Committee.

Elastic Impact of a Pianoforte Hammer. S. BHARGAVA and R. N. GHOSH, Allahabad University. (*Phil. Mag.*, June, 1924.)—Helmholtz in his theory of the effect of the hammer on the piano wire regarded the hammer as elastic and took the time during which the hammer and wire are in contact to be small in comparison with the period of vibration of the wire. Later Kaufmann, after showing that the duration of contact and the period were not very different, developed a theory in which he regarded the hammer as hard. Raman and Banerji, working together, and Das, separately, have extended the theory of the hard hammer. The authors of the paper under review present a theory of an elastic hammer striking a wire, the duration of contact and period being not greatly different.

A wire was struck by a hammer. The approach and recession of the hammer, the motion of the point struck and the motion of a stylus attached to a tuning fork, all were recorded on a moving photographic plate. From the constants of the hammer, the wire and the spring the ratio of duration of contact to period of wire was calculated and from the traces on the plate it was experimentally determined. The length of the wire was 95.4 cm. When the location of the point struck was from 8 to 14.3 cm. from the end of the wire there is remarkably good agreement between the values of the ratio given by theory and by experiment. No blows were struck nearer to the end than 8.2 cm., but when the blow was delivered from 14.3 to 18.1 cm. from the end there is a much larger divergence between the two values. In practice the hammer strikes the wire at a point about one-ninth of its length from the end and here the theory is very closely in accord with experimental results.

It is interesting to note the quantity and excellent character of the work done on musical instruments in India during recent years.

G. F. S.

CURRENT TOPICS.

Wood-preservation Research.—Director E. R. Weidlein, of Mellon Institute of Industrial Research of the University of Pittsburgh, has announced the founding of an Industrial Fellowship on the treatment of timber. This research, which is being sustained by the Grasselli Chemical Company, of Cleveland, Ohio, and is being conducted by Dr. A. M. Howald, has for its purpose a study toward improvement of the methods of applying zinc chloride in the wood-preservation industry.

Investigational work which was begun during 1923 will be continued throughout the present year. An experimental wood-impregnating plant is maintained for practical tests of processes. Research is at present being done under the supervision of Doctor Howald on the development of a method of increasing the permanence of zinc chloride treatments of timber by the addition of petroleum oils.

Emission of Light by Solid Nitrogen and the Origin of the Auroral Spectrum. L. VEGARD. (*Comptes Rendus*, March 31, 1924.)—In the *Philosophical Magazine* of last October Vegard discussed at length the composition of the upper regions of the atmosphere, making use of his photographs of the aurora at different heights. (See a review of the article in JOURNAL OF THE FRANKLIN INSTITUTE, Dec., 1923, p. 856.) He reached the conclusion that solid nitrogen is the chief constituent in atmospheric layers 90 km. or more above the earth. He had bombarded gaseous nitrogen at the temperature of liquid air with cathode rays and had found some similarity between the spectrum thus obtained and that of the aurora. Now he has taken a hoar frost of solid nitrogen, deposited on a surface of copper cooled by liquid air, and directed the cathode rays upon it. Photographs of the spectra were taken for exposures varying from five to thirty minutes, and for velocities of rays caused by differences of potential ranging from 200 to 750 volts.

There has been a mysterious line in the spectrum of the aurora, green and of wave-length 5577 Å. From no known source could it be obtained except from the aurora. Its origin is no longer in doubt, for it appeared in the spectrum of the light emitted by the crystallized nitrogen. In fact, when 700 or 750 volts were used to impel the cathode rays this line of nitrogen "dominated the spectrum just as the green auroral ray dominates the spectrum of the polar aurora." Another green ray from the aurora is similarly found in the spectrum of solid nitrogen and "the blue and violet part of the spectrum of solid nitrogen is practically identical with the most typical auroral spectrum." When the rays cease, the layer of nitrogen stays luminous for about five minutes and there is a residual glow of the same dura-

tion in the aurora also. "The high velocity necessary to produce the green rays and the great variation in their intensity are very remarkable facts from the point of view of physics and this variability can explain some of the color changes seen in the aurora. The residual glow indicates that the new luminous effect is a kind of phosphorescence."

The author suggests that further experiments may permit the determination of the temperature of the region where the aurora originates and of the nature of the cosmical bombarding rays. He goes farther afield and remarks, "It would be interesting to see if other gases such as H_2, O_2, Ar, Ne, NH_3, and NO, in the solid state and bombarded by electric rays, give a luminous effect like that of nitrogen. Should such be the case we may hope to reproduce nebular rays and thus to attain a knowledge of the constitution of stellar nebulæ." In the execution of this design, should he see fit to undertake it, Professor Vegard may well take another captive to the bow and spear of his scientific imagination and experimental skill.

G. F. S.

Annual Report of the Director of the Department of Terrestrial Magnetism, Carnegie Institution. (Year Book No. 22, for the Year 1923.)—Perhaps the most picturesque feature in the activities of the Department of Terrestrial Magnetism was the non-magnetic vessel, the *Carnegie*. For quite a long time she has been ingloriously out of commission at a wharf in Washington and there are no systematic observations taken on the ocean by the department. On land, field work has had largely to do with studying secular and diurnal changes of magnetism. The only new stations of the year were in Haiti, the Dominican Republic and on tributaries of the Amazon. Three or four observers have been kept in the field in Australasia, Central America, Greenland, South America and on islands in the Atlantic and the Pacific.

Regular work has been conducted in the observatories at Watheroo, Australia; Huancayo, Peru; Apia, Samoa. In the Washington laboratory Doctor Barnett has continued his classical investigations on magnetization by rotation. He has used permalloy and the Preuss alloy of iron and cobalt that has high induction in intense fields. Mr. Kotterman has developed the technique of making fine quartz fibres, while the preparation and standardizing of apparatus has claimed the attention of other workers. A side-light on the range of the activities of the department is given by the statement, "Observer W. A. Love was assigned to the party (to Guatemala) in order to determine the geographic positions and orientations (astronomic and magnetic) of the archæological ruins investigated."

"Owing to the extent and accuracy of the accumulated data it has become possible to give answers to some of the greater questions outstanding. For example, there can now no longer be any question that the earth's intensity of magnetization has been steadily diminish-

ing during the past eighty years at a rather large annual rate, namely, about 1/1500 of itself. Even though no statement at present may be made as to how much longer the diminishing will continue, or as to whether the earth's magnetism has been steadily running down for centuries past, what has already been found is of profound bearing upon theories as to the origin of the magnetic field enveloping our planet."

"The continued studies of the sun's magnetic field by the Mount Wilson Observatory, combined with those of the magnetic fields of the earth and the atmosphere by the Department of Terrestrial Magnetism, are resulting in a most interesting array of facts with regard to the magnetic fields of three bodies differing greatly in their physical composition. All three bodies are enveloped by magnetic fields showing some striking general characteristics which seemingly indicate that the origin, strength and orientation of the magnetic field may be primarily dependent upon direction and speed of rotation and upon the size and mass of the rotating body." G. F. S.

Bottled Carbonated Waters.—The so-called "soft drinks" are a striking feature of American life, and the establishment of restrictions on the use of alcoholic beverages has tended to increase the use. The industries now directly and indirectly concerned with the manufacture and sale of these beverages are enormous in extent and have been well-organized under expert engineering and chemical control. Some idea of the nature and methods of such industries will be gained by a visit to the exhibitions at the annual convention of the American Bottlers of Carbonated Beverages at Louisville in November next. The production of carbonated beverages is a very old industry, but in the beginning everything was done by hand; now every step of the procedure is conducted by machinery and human hands do not touch the product at any point.

The first "soda-water" seems to have been made by Joseph Priestley. Townsend Speakman, a Philadelphia druggist, in 1807, flavored this with fruit juices, and thus originated the carbonate beverage. At present a research laboratory at Iowa State College has been endowed by the A.B.C.B. as the national association mentioned above is generally known. Federal statistics show that about eight billion bottles (6½ fluid ounces, slightly less than half a pint) were consumed by the American people last year. It is calculated that the contents will amount to five hundred million gallons, which is nearly five gallons for each inhabitant in the country. H. L.

The Effect of an Electric Current on the Motion of Mercury Globules in Dilute Sulphuric Acid. J. E. P. WAGSTAFF. (*Phil. Mag.*, May, 1924.)—From a fine capillary tube, drops of mercury fall into a glass tube containing dilute sulphuric acid. Platinum electrodes in side-tubes make possible the application of an electromotive force. When this is done the mercury droplets move along

the acid tube, which is about 50 cm. in length, even going uphill if the tube is slightly inclined to the horizontal. They travel in the direction of the applied electromotive force, moving with a constant velocity depending on the radius of the drop. The velocity is, moreover, a linear function of the potential difference between the ends of the tube, and for 100 volts amounted to 20 or 30 cm. per second. The motion of the drop due to gravity is not affected by the potential difference provided that the electrolyte be replaced by an insulating liquid.

A drop of mercury in the dilute acid acquires ions of the metal from the solution and with them a positive charge. Outside of this is an attracted negative charge. Thus a spherical condenser is formed, the two charges being very close together. It is to the electrical interaction of the field with this condenser that the force is due that causes the drops to move in the direction of the electrical field. G. F. S.

Alcohol as a Motor Fuel.—Fuel is king. No greater striving of the nations is to be found at present than that for control of the fuel supplies of the world. For many years coal has been the objective point, but the urge has now shifted, and oil is the desired material. In connection with the development of the combustion motor, the possibility of using alcohol in whole or part has been prominently before engineers for some time. Each nation of importance is anxious to have within its own territory sufficient fuel supplies, and, as the deposits of coal and oil are not distributed equally, investigations are being made to secure such materials as can be produced at will. Alcohol is practically inexhaustible. Starch-containing plants can be grown in unlimited amount and the fermentation is a simple process. Up to the present time the cost of such manufacture has been so far above the cost of standard motor fuels that the alcohol motor has been only suggestive.

France is one of the nations that has taken alarm as to the source of volatile fuel, and elaborate experiments have been undertaken to determine how far a mixture of alcohol and common hydrocarbon fuel can be made practicable. A report on results so far attained appears in the *Ann. d. Chim. Anal. et Appl.* ([2], 1924, **6**, 136), prepared by George Baume. It has been found that absolute alcohol is much better suited for admixture with the hydrocarbons than when water is present. With the absolute form, about equal parts of the two liquids can make a stable mixture. Some adjustment of the motor is needed to secure efficient service, but this problem has been solved. It is claimed that the alcoholized fuel is less likely to produce knocking.

The manufacture of an alcohol containing only traces of water by the ordinary methods is an expensive process. The committee investigating the matter has adapted a method devised by Sydney Young and used in certain French distilleries. It consists in rectifying the alcohol in the presence of benzene. The distillate consists of

benzene, water, and a small quantity of the alcohol; the greater portion of the latter remains in anhydrous form in the still. Operations of this character have been carried on to the amount of several thousand gallons per day. The problem of the denaturing of this alcohol has also been considered. H. L.

The Period of Ionium and the Ionium-Thorium Ratio in Colorado Carnotite and Joachimsthal Pitchblende. F. SODDY and MISS A. F. R. HITCHINS. (*Phil. Mag.*, June, 1924.)—Uranium preparations, four in number, purified from fifteen to eighteen years ago, were examined and the mass of radium that had grown during the interval was determined. For example, 255 g. of uranium in 17.81 years developed 55.7×10^{-12} g. of radium. From the four results it was calculated that the average life of ionium is 110,000 years, that of radium being 2375 years. In 60 g. of ionium-thorium oxides from Boulder, Colorado, the ratio Io: Th was found to be 1:23, while in pitchblende from Joachimsthal (now Jachymov, Czecho-Slovakia) the same two elements were in the ratio 1:.89. G. F. S.

Growing Stock for the Christmas-tree Market.—Instead of futilely berating a sentimentally callous world for denuding our forests of young trees to supply the great annual Christmas-tree market, the Northeastern Forest Experiment Station is trying out the possibility of growing trees purposely to supply that market. In a plantation of two-year-old Scotch pine that the station has just initiated for experimental purposes in coöperation with the Forestry Department of the Massachusetts Agricultural College at Mt. Toby, Massachusetts, Norway spruce seedlings have also been planted, on half the plots, at the centres of the squares formed by the 6 x 6 foot spacing of the young pines. Here it will be possible to test out the feasibility of raising Christmas-tree stock in mixture with a pine plantation, the spruce to be removed when it is large enough for a ready sale. By thinning out the spruce in this fashion, it is hoped that the growth of the other species will not be retarded. By planting half the plots in this way and comparing them at later observation periods with the plots on which pine only has been put in, the success of the experiment will be definitely determined.

Martin Hans Boyè, 1812–1909, Chemist.—In this monograph (Philadelphia, 1924), Edgar F. Smith describes the life and labor of an eminent Philadelphia chemist of the nineteenth century. A native of Denmark, and a graduate of the University of Copenhagen, Boyè came to the United States in order to obtain an open field for research in his chosen profession. He became a geologist and chemist in the first geological survey of Pennsylvania, did chemical work for the geological survey of Delaware, and conducted a private laboratory in partnership with James Curtis Booth. In 1844, the University of

Pennsylvania conferred upon Boyè the degree of Doctor of Medicine in course and that of Master of Arts, honoris causa.

His research work, published in his own name and in conjunction with others, extended into various branches of chemistry, such as methods of analysis, analyses of minerals, syntheses of organic compounds, and problems in inorganic, industrial, physiological, and pathological chemistry. He devised an ingenious method for the quantitative separation of calcium from magnesium. His research with Clark Hare on perchloric ether was pioneer work in the field of high explosives. He and Booth studied the conversion of benzoic acid into hippuric acid in the human body. Boyè devised an industrial process for refining cotton seed oil; the product was bland, colorless, and suitable for culinary purposes as well as for the manufacture of high-grade toilet soap.

Boyè was a founder of the American Association of Geologists, now the American Association for the Advancement of Science, in 1840. From 1845 to 1859, he served as professor of natural philosophy and chemistry in the Central High School of Philadelphia, and installed a laboratory in that institution. One of his pupils was Thomas M. Drown, who became an eminent sanitary chemist. Boyè was the author of textbooks, and of articles in scientific journals and encyclopædias, as well as a translator of scientific treatises. From 1859 until his death in 1909, he lived in retirement at Coopersburg, Pennsylvania. Doctor Boyè was a member of The Franklin Institute for seventy-two years. J. S. H.

Thioacetic Acid.—This organic acid has been prepared hitherto by the action of phosphorus pentasulphide upon acetic acid. H. T. CLARKE and W. W. HARTMAN (*Jour. Amer. Chem. Soc.*, 1924, 46, 1731–1733) find that thioacetic acid may be readily prepared by passing hydrogen sulphide into acetic anhydride containing 2 per cent. of acetyl chloride, acetyl bromide, or hydrogen chloride. The actual yield of thioacetic acid is approximately 70 per cent. of the thoretic yield. Acetyl bromide is a more effective catalyst than acetyl chloride. Neither pure acetyl chloride nor pure acetic anhydride reacts with hydrogen sulphide. J. S. H.

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